Volume 5 June, 1926 Number 6

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

Published Monthly by the American Welding Society
33 West Thirty-ninth Street, New York

American Welding Society

OFFICERS FOR 1926-27

F. M. FARMER, *President*
E. M. T. RYDER, *Senior Vice-President*
C. A. MCCUNE, *Treasurer*
M. M. KELLY, *Secretary*
R. L. BROWNE, *Vice-President*
A. M. CANDY, *Vice-President*
STUART PLUMLEY, *Vice-President*
GEORGE BIRD, *Vice-President*
N. A. WRIGHT, *Vice-President*

DIRECTORS

(Officers listed above are also members of the Board of Directors)

Term Expires 1927	*Term Expires* 1928	*Term Expires* 1929	*Section Representatives*
J. H. DEPPELER	JAMES BURKE	C. A. ADAMS	C. W. BATES
A. S. KINSEY	J. W. MEADOWCROFT	A. M. CANDY	J. C. BENNETT
E. M. T. RYDER	H. A. WOOFTER	A. E. GAYNOR	H. P. DOUD
W. A. SLACK	S. W. MILLER	H. M. HOBART	H. D. KELLEY
T. F. BARTON	E. H. EWERTZ	A. G. OEHLER	J. C. LINCOLN
			J. W. MORRISSEY
			W. L. WARNER
			W. A. SLACK
			G. W. SWAN
			L. G. HICKS
			F. E. ROGERS

PAST-PRESIDENTS

C. A. ADAMS (1919-20)
J. H. DEPPELER (1920-21)
S. W. MILLER (1921-22)
C. A. MCCUNE (1922-23)
T. F. BARTON (1923-24)
E. H. EWERTZ (1924-25)
A. G. OEHLER (1925-26)

CHAIRMEN, STANDING COMMITTEES

Executive—F. M. FARMER
Finance—C. A. MCCUNE
By-Laws—A. M. CANDY
Meetings and Papers—P. W. SWAIN
Membership—J. J. FLAHERTY

W. SPRAGEN, *Editor, Journal*

American Bureau of Welding

(RESEARCH DEPARTMENT OF SOCIETY)

OFFICERS

C. A. ADAMS, *Director*
H. L. WHITTEMORE, 1st *Vice-Director*
A. D. RISTEEN, 2nd *Vice-Director*
WM. SPRAGEN, *Secretary*

CHAIRMEN, RESEARCH COMMITTEES

Electric Arc Welding—H. M. HOBART
Gas Welding—S. W. MILLER
Welded Roll Joints—G. K. BURGESS
Welding Wire Specifications—C. A. MCCUNE
Pressure Vessels—H. L. WHITTEMORE
Thermit Welding—J. H. DEPPELER

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

Copyright 1926, by the American Welding Society,
33 West Thirty-ninth Street, New York.

Subscription $10.00 per year to United States. $11.00 to Canada. Libraries $5.00
Back numbers, per copy: Members, $0.50; Non members, $1.00.

The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication, provided proper credit is given.

Volume 5 **JUNE, 1926** **Number 6**

TABLE OF CONTENTS

Society and Related Activities **Page**

New President 3
Year Book 3
American Bureau of Welding 4
Fall Meeting 4
Section Activities 5
Employment Service Bulletin 6

Technical Papers, Items and Reports

Autogeneously and Electrically Welded Boilers and Containers 7
Discussion of Paper on Autogenously and Electrically Welded Boilers and Containers 27
Discussion by W. L. Warner 27
Discussion by H. L. Whittemore 28
Discussion by J. J. Crowe 29
Discussion by S. W. Miller 30
Discussion Technical Papers Presented at Annual Meeting 32
Discussion Resistance of Shells and Tubes to Internal Pressures 43
Discussion on Calculation of Stresses in Pipes 45
Oxy-Acetylene Welding of Sheet Aluminum 47
X-Ray Tests of Welds 50
Current Welding Literature 58

SECTION OFFICERS AND HEADQUARTERS

PHILADELPHIA

Engineers' Club, 1317 Spruce St., Philadelphia, Pa.

Chairman—P. A. L. Maurhoff, District Manager, Oxweld Acetylene Co.
Secretary—H. E. Hopkins, 709 W. Huntington St., Philadelphia, Pa.

CHICAGO

Monadnock Building, Chicago

Chairman—Jonathan Wolfe, Chicago Surface Lines.
Secretary—Stuart Plumley, Editor, Acetylene Journal.

PITTSBURGH

1841 *Oliver Bldg., Pittsburgh*

Chairman—J. D. Conway, Secretary-Treasurer, Railway Supply Mfg. Assn.
Secretary—H. E. Hollis, P. O. Box 681, Pittsburgh, Pa.

NEW YORK

33 *West Thirty-ninth Street, New York*

Chairman—A. E. Gaynor, J. A. Roebling's Sons Co.
Secretary—A. F. Keogh, Sound Welding Company.

NORTHERN NEW YORK

General Electric Co., Schenectady

Chairman—R. E. Wagner, General Electric Co.
Secretary—F. M. Jefts, General Electric Co.

CLEVELAND

2200 *Chester Avenue, Cleveland, Ohio*

Chairman—John H. Thornton, David Lupton Sons Co.
Secretary—R. K. Randall, Dean, Welding School, Cleveland School of Technology.

SAN FRANCISCO

Rialto Building, San Francisco

Chairman—W. P. Brown, Brown Bros. Welding Co.
Secretary—W. B. Sawyer, Jr., United States Steel Products Company.

LOS ANGELES

P. O. Box 510, Arcade Sta.

Chairman—L. G. Hicks, Standard Oil Co.
Secretary—L. R. Ardouin, U. S. Steel Products Co.

BOSTON

Engineers' Club, 2 Commonwealth Avenue, Boston, Mass.

Chairman—J. A. Shand, Air Reduction Sales Co., Dorchester, Mass.
Secretary—H. P. Peabody, J. A. Roebling's Sons Co.

WESTERN NEW YORK

509 *Morgan Bldg., Buffalo, N. Y.*

Chairman—Robert Siemer, Allan Mfg. & Welding Co.
Secretary—C. D. Miller, Burke Electric Co., Buffalo, N. Y.

DETROIT

Chairman—W. C. Sprau, Barnes Wire Fence Co.
Secretary—A. W. Fry, C. A. Strelinger Co., 149 Larned St. E., Detroit, Mich.

PORTLAND

524 *Oregon Building*

Chairman—J. S. Beall, Beall Pipe & Tank Corp.
Secretary—Samuel Powell, United Metal Trades Association.

AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

Volume 5 JUNE, 1926 Number 6

OUR NEW PRESIDENT

Mr. Farmer, an engineer by profession, was born March 28, 1877, at Ilion, N. Y. He was educated at the Ilion Academy and Cornell University, from which he graduated in 1899 with the degree of M. E. He spent two years with the General Electric Company, two years with the Navy Department as inspector, and

for the past twenty years has been associated with the Electrical Testing Laboratories of New York, of which he is now Chief Engineer. He is a Fellow of the American Institute of Electrical Engineers and a member of the American Society of Mechanical Engineers, the Institution of Electrical Engineers (British), the American Society for Testing Materials and other engineering organizations. He has been active on the committees of these societies, has contributed numerous technical papers to their proceedings, and was president of the A. S. T. M. in 1924. He is the author of "Electrical Measurements in Practice" (McGraw-Hill Book Company), an associate editor of the American Civil Engineers Handbook and a contributor to the Standard Handbook for Electrical Engineers. He has had a wide experience in industrial research, testing and inspection of electrical engineering materials and apparatus—subjects to which he has given special attention being electrical measurements, electrical insulating materials and electric power cables.

Mr. Farmer has been interested in the welding art since the war, at which time he was a member of the Welding Research Committee of the Emergency Fleet Corporation—his particular activities being in connection with the development of standard tests for welded joints. He has been a member of the Bureau of Welding since its organization and was chairman of the committee which prepared "Standard Tests for Welds" issued by the Bureau as Bulletin No. 1. He is chairman of the committee which prepared the current A.I.E.E. Standards for arc welding and resistance welding apparatus. He served on the executive committee of the American Welding Society last year.

YEAR BOOK

The annual membership directory of the American Welding Society, which is published regularly as the August issue of the Journal, will this year be enlarged and changed to be a "Year Book" of the Society.

Among other things, the Meetings and Papers Committee expect to include in the Year Book the Constitution and By-Laws of the Society, a financial statement for the past year, rules governing the actions of the

Meetings and Papers Committee, a description of the American Welding Society, its functions and relation to the industry, value of membership, how to become a member, and publications of the Society, a description of the American Bureau of Welding, its by-laws, aims and activities, committees and members thereof, a statement of the growth of the welding industry and other descriptive matter. There will also be the usual membership list, geographical list, description of contributing companies and an advertising section. No effort will be spared to make this Year Book the outstanding feature of the Society's publications. Suggestions from members as to other features which may be included will be welcomed by the Meetings and Papers Committee.

The members of the Society are requested to cooperate by returning promptly the card indicating their address and connections, which is to be used in the compilation of the membership directory. These cards will be mailed shortly to all members.

AMERICAN BUREAU OF WELDING

The Annual Meeting of the American Bureau of Welding was held in conjunction with the Annual Meeting of the Society. Four papers were featured outlining some of the unsolved fundamental problems in the welding field. At that time it was unanimously agreed that the solution of many of these problems would lead to important commercial developments and extensions in the use of welding.

Another meeting of the Bureau was held on June 2, at which specific plans were proposed for the conduct of fundamental research problems and methods of financing this work. A special committee was appointed to make recommendations.

The Electric Arc Welding Committee reported that during the last year it had concentrated its attention on finishing up the tests made during the war under the auspices of the Emergency Fleet Corporation. Analyses of these test results are now being made and the work of analysis divided among a number of the members of the committee.

The Gas Welding Committee is working on the study of welds to be subjected to high temperature. The supervision of this work is being handled by a small sub-committee working under the auspices of the San Francisco Section of the American Welding Society.

The Welded Rail Joint Committee is devoting considerable attention to the study of the stresses involved in rail joints under varying service conditions and also under different energies of blow and distances of support of specimens in the repeated impact testing machine built by the committee. In these stress measurements, a device perfected by the Bureau of Standards called the "telemeter" is being used.

The launching of a joint pressure vessel investigation under the auspices of the American Welding Society and the American Society of Mechanical Engineers has now been approved by both organizations and the American Bureau of Welding has been instructed to proceed with the organization of a suitable committee representing scientific and technical organizations interested, contributing companies and also experts from the various phases of science involved in the several problems called for in the proposed program of the committee. National Research Council has agreed to act as treasurer for the funds. It is expected that an organization meeting will be held some time in September.

ADDITIONS TO JOURNAL

At a recent meeting of the Meetings and Papers Committee, it was decided to add a news column in the Journal concerning the prominent members identified with the American Welding Society. News of changes of business connections, promotions and special accomplishments are particularly desired.

FALL MEETING

The Fall Meeting of the American Welding Society will be held in Buffalo on November 17, 18 and 19. An International Welding and Cutting Exposition will be held in connection with this Fall Meeting and will open Tuesday afternoon, November 16.

Further details will be announced in the next issue of the Journal. The technical sessions include railroad, welding apparatus, welding science in the engineering curriculum of universities, and welding in a gaseous atmosphere. The entertainment includes a trip to Niagara Falls, a view of the Falls from the American side, with

an inspection trip through the Niagara Falls Power House, a buffet supper on the Canadian side and a special illumination of the Falls. There will be the usual annual Fall banquet, which is expected to be an outstanding success, and a meeting of the American Bureau of Welding, the Board of Directors and the Welding Wire Specifications Committee.

SECTION ACTIVITIES

Western New York

A regular meeting of the Western New York Section was held on April 26 in the Engineering Societies Room, Hotel Statler. Mr. W. H. Carter, of the DuPont Engineering Company, presented a brief review of the practical applications of lead burning or welding and also the welding of aluminum. His remarks dealt particularly with the use of these methods in the chemical industry. Samples were shown to illustrate what can be done in the welding of these two metals in various positions.

S. W. Miller presented a paper on "Welding in the Manufacture and Repair of Pressure Vessels" at the May meeting of this Section, which was held on the 26th at the Hotel Statler. The same paper was presented at the regular session of the Master Boiler Makers Association in the morning of the same day.

New York

The last meeting before the summer vacation was held on May 18 in the Engineering Societies Building. Mr. C. J. Holslag presented a review of his experience on the electric welding of the new stainless steels, including technique and service results. Welded samples were passed around illustrating the progress made. Mr. George L. Walker, assistant research engineer of the Air Reduction Sales Company, presented a comprehensive review on gas welding of tool steel, including limitations, approved methods, heat treatment, fluxes and precautions. The paper was illustrated by lantern slides. A smoker was enjoyed by all present.

San Francisco Section

A regular monthly meeting of the San Francisco Section was held on Friday, May 21, at the Engineers Club. Mr. W. J. McRae, of the Thomson Electric Company, presented a review on Resistance Welding. Mr. J. W. Owens also spoke informally.

Portland

An informal organization meeting of the Portland Section was held on Feb. 18, 1926. This was followed by a formal organization meeting at the Benson Hotel on March 18. A motion to organize the Portland Section was unanimously carried and a Nominating Committee appointed to nominate officers.

Mr. F. W. Small, of the Steel Tank & Pipe Company of Oregon, presented an interesting talk at the April 21st meeting of the Section on the progress and experience to date on the construction of the welded pipe line for the East Bay water project for Oakland. The pipe line is to be 90 miles in length and the thickness of the pipe ⅜ to ½ inch. It is probably the largest job of its kind in the world.

The following officers have been elected by the Portland Section to serve for the coming year. Chairman, J. S. Beall, Beall Pipe & Tank Co.; First Vice-chairman, Fred C. King, King Bros. Boiler Company; Second Vice-chairman, George C. Dierking, Steel Tank & Pipe Company of Oregon; Treasurer, Ray I. Smythe, Willamette Iron & Steel Works; Secretary, Samuel Powell, United Metal Trades Association.

Bound Volumes Journal
$5.00 per copy
Index of Subjects and Authors Included
Years 1922, 1923, 1924, 1925

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to Society headquarters.*

POSITIONS VACANT

V-31. Salesmen and Estimator wanted. Required by one of the largest and best established job welding concerns in New York. Preferably a man who has experience or one who has a fair knowledge of welding, both gas and arc, and who is accustomed to doing business with large service stations and fleet owners.

An interesting proposition will be made to the right man, which assures a good income on a salary and commission basis, to a live wire who can produce. All details will be treated in confidence.

V-32. Experienced welder or welding engineer wanted who has had broad experience in tank welding including bath boiler construction. In our Seamless Division we have decided to develop welding of certain types and styles of containers, and we want experienced man to follow work through various stages including testing.

V-33. Welder wanted with experience in electric arc and oxy-acetylene welding.

Services Available

A-41. Electric welder desires position. Have had 8 years' experience, including repair, machine and boiler work on the Erie R. R. and high pressure vessel and tank work of Standard Oil Co.

A-42. Electric welder desires position. Have had 10 years' experience, including six with the Tide Water Oil Co., three years with Standard Oil and one and one-half years with M. W. Kellogg Co.

A-43. Oxy-acetylene welder desires position. Have had five years' experience and can weld any kind of work, including aluminum.

A-44. Acetylene welder desires position. Have had seven years' railroad shop welding experience and four years' industrial welding. Desire position as Foreman or Supervisor. Have credentials as welder, also as instructor.

A-45. Oxy-acetylene welder desires position. Have had experience and can furnish reference.

A-46. Electric welder, 19 years' experience in shipyards, railway shops and general welding work. Employed as welder, demonstrator, instructor, engineer and supervisor. Drafting room and repair experience. Familiar with all the different makes of oxy-acetylene torches and regulators, and can make own repairs. Can furnish best of reference as to character and ability. Prefer to locate in Philadelphia.

A-47. Acetylene welder desires position. Has had 6 years' experience, including repair work, pipe and boiler construction. Can give references.

Autogenously and Electrically Welded Boilers and Containers

By E. Hohn,[1] Zurich, Switzerland

The increasing employment of autogenous and especially of electric welding has led to an investigation of the strength and tenacity of parts welded together. The expense of this investigation has for the most part been borne by the Swiss Union of Steam Boiler Users. There are now no further obstacles in the way of employing such welded joints; for example, flanges welded on are stronger than those screwed on or rolled on, and rings welded on stiffen manhole walls much better than do those riveted on. The author proposes a new method of safeguarding welded seams by means of straps welded on, and gives examples of welded boilers, compressed-air receivers and other types of pressure vessels.

The employment of boilers and pressure vessels having welded instead of riveted seams is increasing. Included among these are vessels whose seams must be welded because the thickness of the walls does not allow of riveting. In the case of those with thinner walls, the welding of the seams often affords other advantages, among which may be mentioned permanent tightness; further, welding is almost always cheaper than riveting.

The most efficient process of welding today is that of welding by means of water gas; with this process plates of such thickness may be welded that other processes cannot deal with them. But it is only very large works which can equip themselves for water-gas welding; medium-sized works and the trade generally are confined to oxyacetylene welding and, in recent times, to electric welding.

In oxyacetylene welding the plate is brought to a welding heat at the seam, and close to the points to be welded to a red heat. This causes the metal to expand, and during cooling stresses arise. In tests carried out in 1921[2] it was found that in a plate 22 mm. in thickness which had been heated at a spot 20 cm. in diameter to a red heat, the particles were permanently displaced as follows:

Diameter of spot measured	contraction	ratio
159.8 mm.	3.02 mm.	0.0189
239.6 mm.	3.17 mm.	0.0132
559.9 mm.	2.89 mm.	0.0052

The magnitude of the displacement depends on the width of the edge: the wider the plate, the greater the displacement. By annealing several times these displacements are reduced.

In local heating of this kind strains remain in the plate, and

---

[1] Chief engineer, Swiss Association of Steam-Boiler Users.

[2] Höhn, Tests with Autogenously and Electrically Welded Boiler Parts, page 49, Zurich, 1921. Speidal and Wurzel.

Augmented text of a paper presented at a meeting on the General Union of German Steam Boiler-Inspection Association at Karlsruhe. Translated from *Zeitschrift des Vereines deutscher Ingenieure*, January 23 and February 6, 1926, pp. 117-122 and 194-196.

their presence was proved by cutting out strips from the plate as shown below.

Length before cutting	Permanent contraction	Ratio
$l = 155.59$ mm.	$\Delta l = 0.05$ mm.	$\epsilon = \Delta l : l = 0.00032$
235.24 mm.	0.10. mm.	0.00042
555.85 mm.	0.10 mm.	0.00018

In other cases the permanent contraction was even greater. The stresses may be calculated from Hooke's law. It is true these measurements were not accurate enough for numerical conclusions to be deduced from them with absolute certainty, especially as the strips of plate had been stressed in two directions before being cut out. The stresses may be eliminated by subsequent annealing of the entire plate.

Difficulties of this kind have for the most part been overcome by electric arc welding. Here the zone of heating and the duration of heating are limited. Besides, electrically fused iron adheres better than autogenously fused iron, because the arc produces crater-like cavities in the metal which are filled by the electrically fused metal. These advantages make electric welding exceedingly suitable for welding structural parts to each other and to plates.

Among the numerous publications on autogenous and electric welding issued by the Swiss Union of Steam Boiler Users in Zurich, the following deserve attention:

Versuche mit autogen geschweissten Kesselblechen 1914 (Tests with autogenously welded boiler plates, 1914).

Versuche mit autogen and elektrisch geschweissten Kesselblechen (unter Mitwirkung des Schweizerischen Azetylen-Vereins) 1921[3] [Tests with autogenously and electrically welded boiler plates (in cooperation with the Swiss Acetylene Society) 1921[3]].

Uber die Festigkeit elektrisch geschweisster Hohlkörper 1923[4] (On the strength of electrically welded hollow vessels, 1923[4]).

Nieten und Schweissen der Dampfkessel, 1925[4] (Riveting and welding of steam boilers, 1925[4]).

Tensile Strength of Autogenously and Electrically Welded Seams (Welding of Joints)

(*a*) *Autogenous Welding.* For these tests the test pieces were cut from welded plate, and were not welded by themselves. Thickness, 1.2 cm.; bars with thickened seam; V-joints welded from one side.

Cold-Bending Tests, 1914. Diameter of pin, 1.2 cm.; 52 bars, mean angle bent through, 162.5 deg.; mean radius of curvature, 1.83 cm.

Notched-Bar Impact Tests, 1914. Notch, 0.4 cm. in diameter; height over the notch, 1.5 cm.; 78 samples; mean work of deformation 5.98 m-kg. per sq. cm., mean angle bent through, 6.4 deg.

(*b*) *Electric Welding* (1923). Thickness of bars, 1.0, 1.7, and 2.5 cm.; shape of joints, *V* (Fig. 35), V* (Fig. 36), and X or

[3] Zurich 6, Speidel & Wurzel.
[4] Berlin, Julius Springer.

double V (Fig. 37); electrodes, wound (English), paste covered (Swedish), and bare (German).

Tensile-Strength Tests. Number of test, bars, 264, of which 184 were welded by using Quasi-Arc electrodes; see Table 2.

TABLE 1. STRENGTH OF AUTOGENOUSLY WELDED SEAMS

Tensile-Strength Tests

27 bars (1914)	Fracture in seam, breaking load 2.56 tons per sq. cm.
9 bars (1921)	Fracture in seam, breaking load 2.9 tons per sq. cm.
25 bars (1914)	Fracture outside of seam, breaking load 2.8 to 3.0 tons per sq. cm.
6 bars (1921)	Fracture outside of seam, breaking load 3.4 tons per sq. cm.

TABLE 2. TENSILE STRENGTH OF ELECTRICALLY WELDED SEAMS

Plate thickness *s*, cm	1.0		1.7			2.5		
Form of joint	*V*	*V*•	*V*	*V*•	*X*	*V*	*V*•	*X*
Mean value, tons per sq. cm.	>3.49	>3.70	>3.71	>3.85	3.61	3.45	3.68	3.61
Fracture outside of seam (number of bars)	3	5	2	2	1	...	...	...
Largest single value, tons per sq. cm.	4.04	4.24	4.16	4.18	4.02	4.10	4.19	4.00
Smallest single value, tons per sq. cm.	1.90	2.90	2.71	3.34	2.94	2.02	3.28	2.07

Average 3.63 tons per sq. cm. for 148 bars welded with Quasi-Arc-electrodes.

TABLE 3. COLD-BENDING TESTS OF ELECTRICALLY WELDED SEAMS

Thickness of plate *s*, cm	1.0		1.7			2.5		
Form of joint	*V*	*V*•	*V*	*V*•	*X*	*V*	*V*•	*X*
Mean angle of bending, α deg.	67.7	78.6	33.2	31.9	36.5	20.8	23.2	30.5
Largest individual bending angle, α deg	180	180	57	68	75	37	37	49
Smallest individual bending angle, α deg	12	16	17	14	14	5	11	18

TABLE 4. NOTCHED-BAR STRENGTH *K* OF ELECTRICALLY WELDED SEAMS

Thickness of plate *s*, cm	1.0		1.7			2.5		
Form of joint	*V*	*V*•	*V*	*V*•	*X*	*V*	*V*•	*X*
Mean value, m-kg. per sq. cm.	5.3	5.0	2.9	4.0	5.3	2.7	3.4	4.0
Highest single value, m-kg. per sq. cm.	12.9	14.8	7.4	11.1	12.1	9.4	13.6	10.4
Lowest single value, m-kg. per sq. cm.	1.2	1.1	0.6	0.6	0.8	0.45	0.2	0.85

Cold-Bending Tests. Diameter of pin = plate thickness; distance of supports, 10.5 cm.; number of test bars, 264, of which 148 were welded with Quasi-Arc electrodes; see Table 3.

Notched-Bar Impact Tests. Table 4. Height of bar over the notch, 15 mm.; width of bars, 1.0, 1.7, 2.5 cm.; number of test bars, 417, of which 240 were welded with Quasi-Arc electrodes.

The seams of the bars tested were thickened in welding but were flattened down level before testing. The two ends of the welded seam were taken off. As to form of bars, kind of stressing, and especially as to conclusions drawn from the tests, reference should be made to the publication already mentioned.[5]

The tensile strength of electrically fused iron is high, the notched-bar strength, average, and the cold-bending strength, small. A V-seam is considerably strengthened if it is "root-welded" or welded at the back (see Fig. 36); in autogenous welding this cannot be done very well and sometimes not at all because of the double heating. On the other hand, autogenously welded V-seams may be additionally welded electrically. X or double V-joints can only be made on thick plates, 2 cm. or thicker; they have approximately the same tensile strength as the V-seams additionally welded at the root; the difference in tensile strength of thin and thick

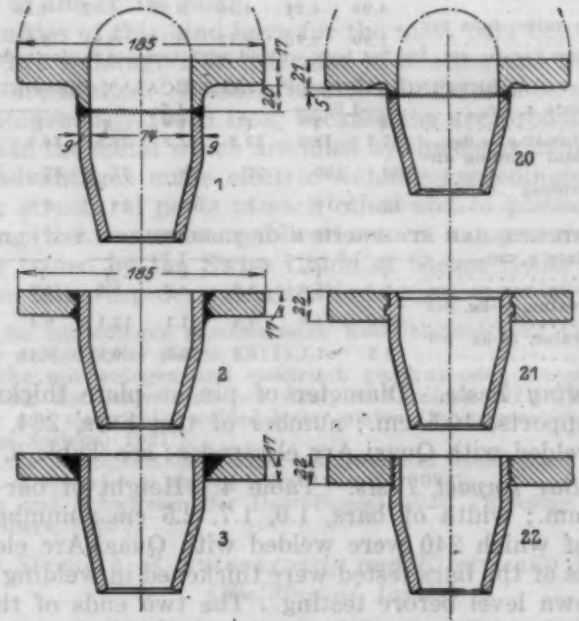
[5] On the strength of electrically welded hollow vessels.

bars is small. With plates of equal thickness Double V-seams show higher bending strength and notched-bar strength than V-seams and V* seams.

The type of electrode is very important. Wound electrodes have given best results, some bare electrodes were useless. Of the personnel employed in the tests, some were beginners; today probably better results would be obtained.

Strength of Boiler Parts Welded Autogenously and Electrically (1921)

Bosses, stays, and feet are welded to boilers, flanges, and tubes to an increasing extent. Such connections must be tested as to tensile strength.



Figs. 1 to 6. Various methods of fastening flanges to tubes

Welded Flanges. The various types of flange fastenings are shown in Figs. 1 to 6. The flanges tested have the same dimensions. The testing arrangement is shown in Fig. 7. The number of test pieces was 72, and the results obtained are given in Table 5. According to this average breaking loads are related to each other as follows:

For types	1		2		20		3
as	68.4	:	64.7	:	48.0	:	30.4
or as	100	:	95	:	70	:	44

The strongest welded joint for flanges is therefore type 1. If a flange is welded on according to type 3, then it should not be stressed except as shown in Figs. 8 to 11.

The few electrically welded flanges showed greater strength than those welded autogenously.

Since these tests were carried out new flange connections have been devised, but they can only be made by electric welding. The joints are sufficiently strong if the seams have sufficient cross-sectional area and are always given bulging profiles (never hollow ones), if the flange thickness or the distance from the seams is great enough, and if the tube wall is not less than 0.6 cm. in thickness.

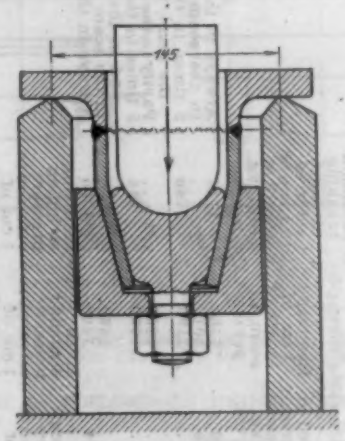


Fig. 7. Arrangement for testing welded flanges

Screwed or rolled flanges such as types 21 and 22, Figs. 5 and 6, are not as strong as welded flanges. They do not withstand deformation nearly as well, and with but slight deformation they lose their strength. But flanges are often overstressed, especially by tightening down nuts, and rolled and threaded flanges must therefore be thick enough so that the elastic limit of the material is not exceeded.

Welded-On Reinforcing Rings. Whether it is practical to weld on a punched or unpunched disk for stiffening a plate was investigated by tests with types 4, 5, and 23, Figs. 12 to 14, with rings welded on, and with type 6 with an inserted flange or boss, Fig. 15, in the arrangement shown in Fig. 16—for results see Table 6. In type 4 the outer surface of the ring was cylindrical, in type 5 it was conical. The average pressures required to force off the disks were as follows:

For types	4	5	23	6
as	48.3	38.9	60.6	53.6
or as	79.7	64.2	100	88.4

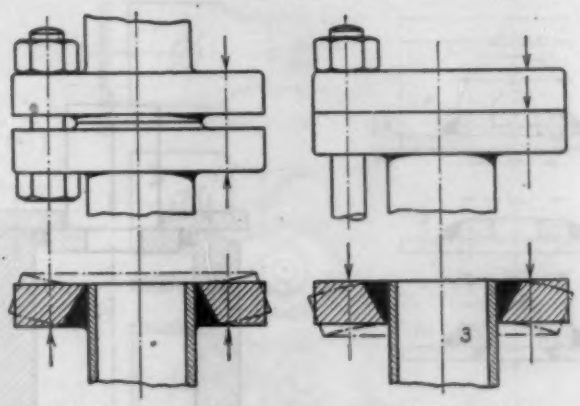
The greatest strength is shown by rings welded on both sides (23) and by flanges or bosses inserted into the plate (6), but for these the plate must be flat.

TABLE 5. TESTS OF FLANGED FASTENINGS PRODUCED BY AUTOGENOUS AND ELECTRIC WELDING AND BY ROLLING AND THREADING

Types (Figs. 1 to 6)	Number of tests and kind of welding	Mean breaking load, tons	Maximum breaking load, tons	Minimum breaking load, tons	Mean Breaking Strength: Referred to fractured cross-section, kg. per sq. cm.	Mean Breaking Strength: Referred to 1 cm. of length of seam, kg. per cm.	Minimum breaking strength referred to 1 cm. of length of seam, kg. per cm.	Fracture
1	27 auto.	68.4	88.0	46.4	2830	2560	1740	Always in the seam
	1 elec.	80.6	...	...	3340	3010	...	In the seam
2	18 auto.	64.7	98.0	52.0	...	2190	1760	9 times in the seam; 9 times partly in the seam, partly in the tube wall
	1 elec.	64.8	...	...	...	2200	...	Partly in the seam, partly in the tube wall
3	12 auto.	30.4	46.8	24.8	...	1030	840	9 times in the seam, 3 times in the seam and in the tube wall
	1 elec.	55.0	...	...	...	1860	...	In the seam
20	4 auto.	48.0	60.0	40.0	1990	1800	1500	Always in the seam
		Mean stripping pressure	Maximum stripping pressure	Minimum stripping pressure	Mean stripping pressure referred to 1 cm. of adhering surface	Mean stripping pressure referred to 1 cm. of length of joint	Minimum stripping pressure referred to 1 cm. of length of joint	
21	4 rolled	33.05	45.0	23.4	510	1120	790	
22	4 threaded	34.92	37.8	31.5	540	1200	1080	

As testing welde-on bosses by the forcing-off method was not sufficient, their adhesive power was further tested by elongation of corresponding test pieces, Figs. 17 to 22, the results being given in Table 7.

These tests confirm the above conclusion as to the adhesion of rings to plates. According to this, welded-on rings are effective



Figs. 8 to 11. Correct method of welding flange Autogenously on one side (Type 3) for two cases of loading

TABLE 6. WELDED-ON REINFORCEMENTS

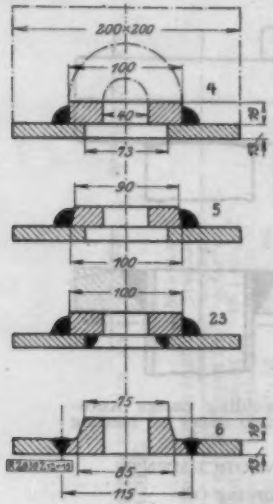
Types	Number of samples and type of welding	Forcing-Off Pressure Mean, tons	Forcing-Off Pressure Maximum, tons	Forcing-Off Pressure Minimum, tons	Forcing-Off Pressure Referred to Length of Seam Mean, kg. per cm.	Forcing-Off Pressure Referred to Length of Seam Minimum, kg. per cm.	Fracture
4	11 auto.	48.3	62.2	32.8	1540	1010	Always in the seam
	1 elec.	30.0	....	....	950	....	In the seam
5	13 auto.	38.9	67.2	17.8	1240	570	Always in the seam
	1 elec.	56.6	....	....	1800	....	In the seam
23	10 auto.	60.6	85.0	26.2	....	....	In the seam
6	26 auto.	53.6	80.0	32.0	1480	890	16 in the seam 10 in the ring
	2 elec.	51.5	....	....	1420	....	1 in the seam 1 in the ring

reinforcements of holes in the walls of tanks and boilers. The rings or disks must be welded on both sides. The seam at the inner edge especially strengthens the hole in the plate, and it is therefore inadvisable to omit it. Bevel-edged rings are not desirable. The welding material must be added copiously, until the seam has a bulging profile (or cross-sectional boundary).

If the welding is done electrically, openings such as manholes, etc., may be reinforced by rings welded on the outside or inside (Fig. 54). In the case of thick plates there should be both inside and outside reinforcement. However, the reinforcing effect of rings thus welded on is greater than that of riveted rings. In the latter case the plate is weakened by the rivet holes, and further, the joint between the ring and plate is not very tight, and dependence has to be placed mainly on calking.

Welding of Plates Perpendicular to Each Other. In boiler con-

struction, and even more so in building construction, the problem often is to join plates perpendicular to each other. It is possible, of course, to weld such plates electrically, and this may be permissible in building construction. Various arrangements (Figs. 23 to 28) were tested as to strength by means of the device shown in Fig. 29, the results being given in Table 8.



Figs. 12 to 15. Welded-on reinforcements (Types 4, 5, 23, 6)

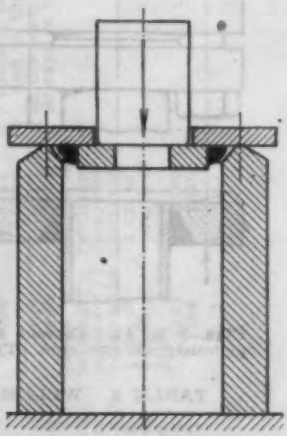


Fig. 16. Arrangement for testing welded-on reinforcements

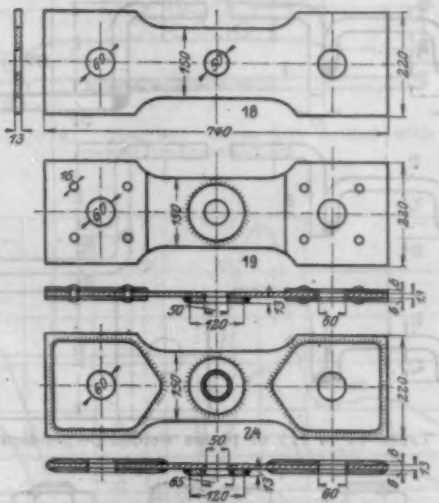
TABLE 7. BARS WITH AND WITHOUT AUTOGENOUSLY WELDED-ON REINFORCING RINGS

Types	Cross-Section of Bar: Width, cm.	Cross-Section of Bar: Thickness, cm.	Yield point, tons	Maximum load, tons	Fracture	Elongation of bar, mm.	Lengthwise expansion of hole, mm.
18 smooth	14.72	1.36	32.5	48.8	Not broken	20 -200	50-67.8
	15.02	1.29	32.0	49.0	Fracture at hole	20 -200	50-69.0
19 rings welded on outside	15.00	1.30	40.0	66.9	Fracture at head of bar	15 -200	50-54.9
	15.03	1.30	43.0	68.7	Fracture at head of bar	14 -200	50-54.9
	15.00	1.30	41.0	68.5	Fracture at head of bar	19 -260	50-56.4
	15.00	1.35	41.0	69.8	Plate fractured in hole, ring intact at one-half of bar	11 -200	50-52.9
24 rings welded on outside and inside	15.01	1.24	42 to 43	74.7	Plate fractured at hole, below ring, which is partly detached	19.3-200	50-58.3
	15.01	1.20	43.0	76.0	Fracture in one side of hole in plate and ring	23.6-200	50-60.1

According to this table the comparative strengths were as follows (see Figs. 23-28):

For types	7		8		9		10		11
as	75.2	:	52.3	:	40.3	:	33.2	:	49.9
or as	100	:	70	:	54	:	44	:	67

The most reliable was type 11, the seams of which were only under tensile stress, although it did not exhibit the highest strength. Of the types under shearing stress, 7 to 9, type 7 gave the best results; in this type one of the plate edges must extend beyond the other by two or three times the plate thickness. Type 10 is inadmissible in boiler construction for important parts.



Figs. 17 to 22. Tensile-strength test bars with welded-on reinforcing rings (Types 18, 19, 24)

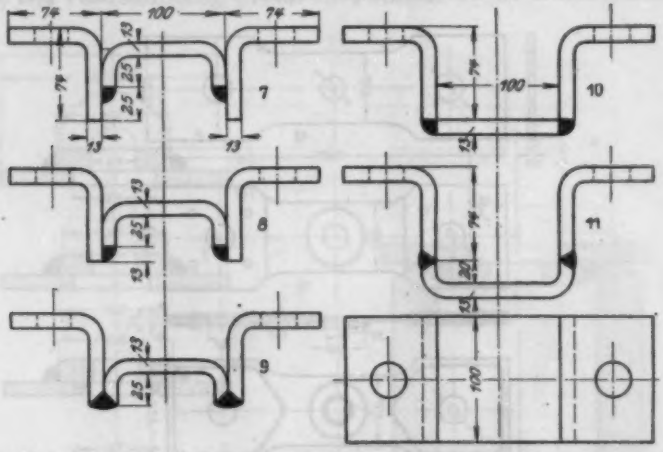
TABLE 8. WELDING OF PLATES PERPENDICULAR TO EACH OTHER

Types	Number	Fracture	Mean breaking load, tons	Maximum breaking load, tons	Minimum breaking load, tons	Mean breaking strength referred to 1 cm. of length of seam, kg. per cm.	Minimum breaking strength referred to 1 cm. of length of seam kg. per cm.
7	47 auto.	In one or both seams	75.2	91.6	33.0	3760	1650
	9 auto.	Outside of the seams	83.2	93.5	75.0	....	....
	3 elec.	In one or both seams	59.3	61.0	56.0	2960	2800
8	54 auto.	Always in one or both seams	52.3	68.6	22.6	2610	1130
	3 elec.	In one seam	52.8	60.6	43.0	2640	2150
9	54 auto.	Always in one or both seams	40.3	58.3	21.6	2010	1080
	3 elec.	In one or both seams	36.9	38.2	35.6	1840	1780
10	54 auto.	Always in one or both seams	33.2	66.8	19.8	1660	990
	3 elec.	In one seam	35.5	43.1	22.4	1770	1120
11	44 auto.	43 in one seam, 1 in both seams	49.9	72.2	36.5	2490 [1]	1820 [1]
	11 auto.	Outside of the seams	67.0	76.2	60.0	.... [2]	.... [2]
	1 elec.	In one seam	48.0	...	...	2400	....
	1 elec.	Outside of the seams	64.8	...	...	....	....

[1] Mean tensile strength $\beta = 1920$; minimum 1400 kg. per sq. cm.
[2] Mean load = 2580; minimum; 2300 kg. per sq. cm.

Welding of Corroded Parts. In order to test the admissibility of welding of boiler plates pitted by rusting, test bars were drilled as shown in Figs. 30 and 31 and the cavities filled by welding. The mean values of the results of these tests are given in Table 9.

In this table values for the expansion and contraction have been added, although, contrary to the case of ordinary test bars, these figures because of the presence of welded seams do not really mean anything. The autogenously welded bars were curved to a greater extent than the others. Since electric welding has now attained a



Figs. 23 to 28. Types (7 to 11) of plates welded perpendicular to each other

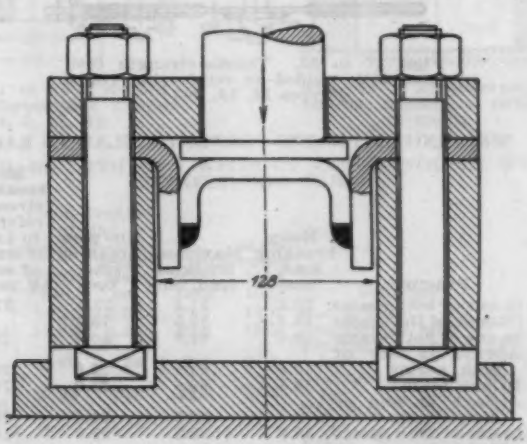


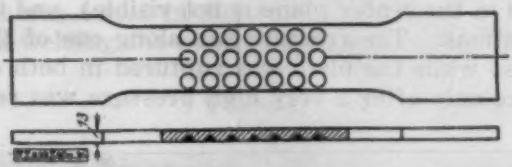
Fig. 29. Arrangement for testing plates welded perpendicular to each other

TABLE 9. TEST BARS DRILLED AS SHOWN IN FIGS. 30-31 AND WELDED

Types	17	13 Fracture outside of weld	13 Fracture in the weld	13 Fracture outside of weld
Number of test bars and type of welding	2 unwelded	11 autogenous	13 autogenous	1 electric
Yield point, tons per sq. cm.	2.31	2.27	2.25	2.22
Tensile strength, tons per sq. cm.	3.44	3.48	3.40	3.49
Contraction, per cent	59.5	56.2	35.5 [1]	55.0
Elongation (20 cm.), per cent	30.2	23.1	18.3	16.1
Quality index, $\beta\gamma/100$	1.4	0.83	0.62	0.56

[1] In 4 samples.

certain degree of perfection, such corroded areas should no longer be welded autogenously, but electrically only. However, even with electric welding the greatest caution is required; in welding fairly large areas it is best to stop occasionally so that the plate may cool down.



Figs. 30 to 31. Test bar (Type 13) drilled with conical countersinkings

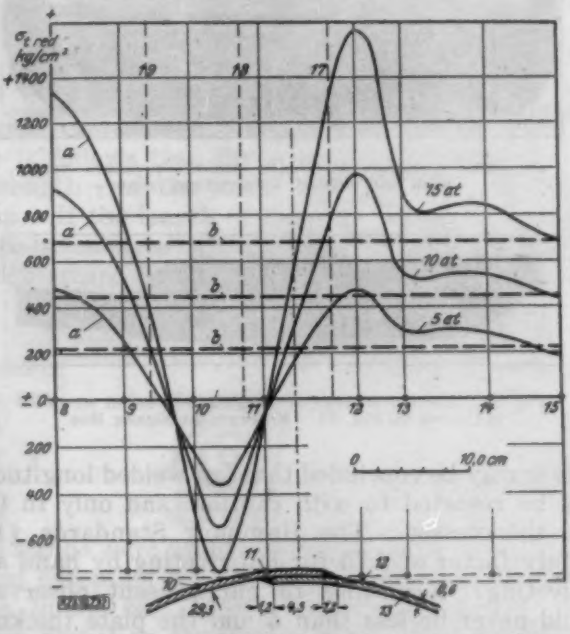


Fig. 32. Course of Peripheral stresses $\sigma_{t\ red}$ in the lap-welded longitudinal seam of a cylindrical shell (a Result of measurement; b Result of calculation)

LAP-WELDED SEAMS AND STRAPPED JOINTS

Lap-welded test bars show a high tensile strength, but in the case of hollow cylindrical vessels, high bending stresses appear in the longitudinal seam.

While in a lap-welded bar the two seams are stressed equally, this is not the case in longitudinal shell seams. Results of measurements[6] (Fig. 32) indicate that the greatest bending stresses occur in the seam of the exterior lap. A further proof that cylin-

[6] Festigkeit elektrisch geschweisster Hohlkörper (Strength of electrically welded hollow bodies), page 87.

drical shells are stressed greatest in lap-welded longitudinal seams is given by the behavior of a vessel in a pressure test which was carried to destruction, Figs. 33 and 34. Here the maximum inside diameter was 80 cm. before and 87 cm. after the test, the average plate thickness 7.9 mm., the length between outside seams 2 m. (a circular seam in the center plane is not visible), and the maximum pressure 83 atmos. The fracture ran along one of the two longitudinal seams; while the plate was ruptured in both of the seams, this took place only after a very high pressure was reached.

Fig. 33. A burst electrically welded pressure vessel with lap-welded longitudinal seam

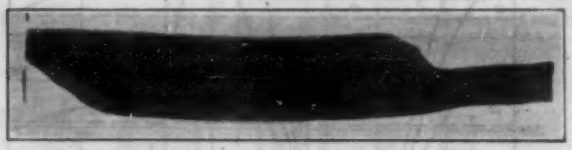


Fig. 34. Etched section of longitudinal seam at point indicated in Fig. 33. Fracture at zigzag line

From this it may be concluded that lap-welded longitudinal joints should only be resorted to with caution, and only in the case of small plate thicknesses. The Hamburg Standards (1905) prescribe a safety factor of 4.75 for lap riveting by hand and 4.5 for machine riveting. According to our present observations this factor should never be less than 5 and the plate thickness should be limited. For welded vessels it should not exceed 0.8 to 0.9 cm. However, whether lap-welded joints should be used at all in boilers is questionable.

Lap-welded longitudinal seams in cylindrical vessels also make it difficult to join on the heads, the more so in the case of welded seams than in that of riveted seams.

However, the same limitations do not apply to lap-welded circular seams. Here bending stresses are not nearly as pronounced as in longitudinal seams, because both seams are stressed alike and then only one-half as much as are longitudinal seams. For this reason the circular seams of the vessel shown in Fig. 33 remained entirely unaffected.

Straps Welded on on One Side behave similarly to lap-welded

joints. Here also bending stresses appear. In one case a vessel tested under water pressure burst along the seam of a parallel strap, but only under very high stress.

Double Straps Welded On. A rectangular strap can be welded to the plate at the ends, at the sides, or all around. The behavior of such joints was tested in 108 bars altogether.

In head end welding the resistance to wrenching off is

$$\delta = \frac{Q}{2F}$$

in which Q in the breaking load in tons and F the surface area of the strap in sq. cm. In lateral welding the resistance to wrenching off (pure shearing strength in this case) is

$$\gamma = \frac{Q}{2F'}$$

in which F' is the surface area of the side.

Tensile-strength tests gave the results presented in Table 10. From these it follows that the wrenching-off strength δ and the shearing strength γ of the joints decrease with increasing thickness of strap. If the length of the side exceeds a certain amount, then fracture takes place in the straps. Such was the case generally even with straps 8 cm. in length and 0.6 to 1.2 cm. in thickness.

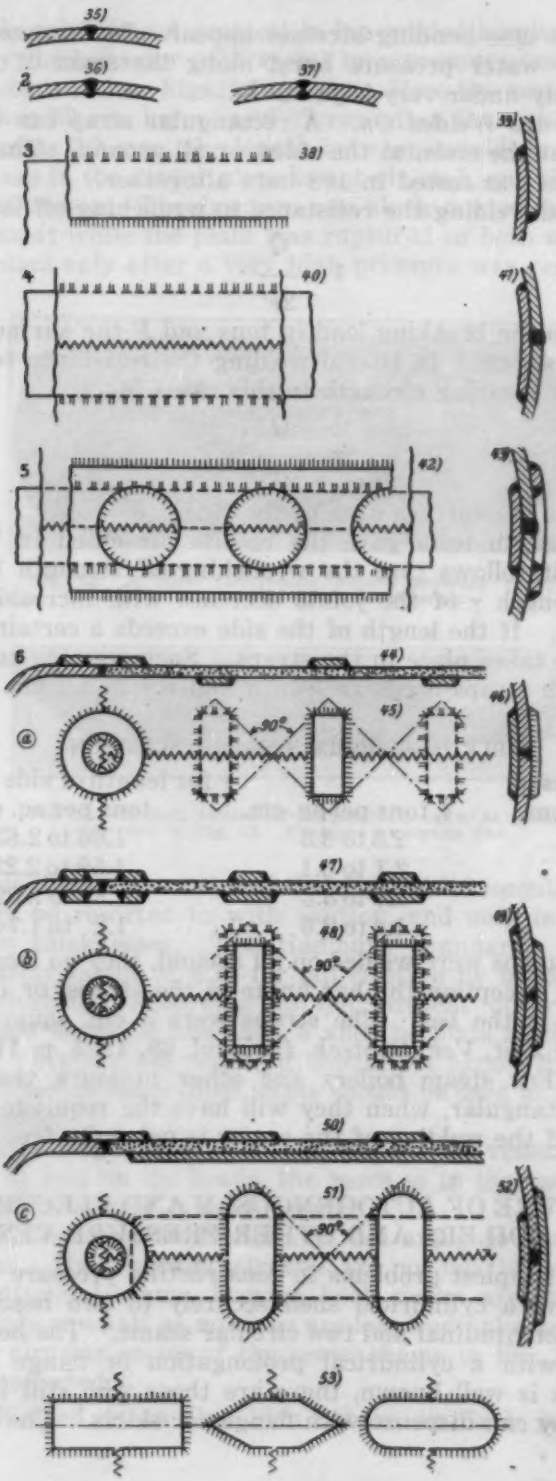
TABLE 10—DOUBLE STRAPS WELDED ON

Thickness of straps, cm.	δ, tons per sq. cm.	γ for length of side — 6 cm. tons per sq. cm.
0.6	2.3 to 3.3	1.66 to 2.83
0.9	2.1 to 3.1	1.59 to 2.22
1.2	1.7 to 3.3	1.33 to 2.09
1.5	1.4 to 2.6	1.2 to 1.74

When the straps were welded on all around, they no longer broke off. Without exception the bar broke in the straps, or in case of thick straps, in the bar. The straps were 5 cm. square or rectangular (see *Zeit. Ver. Deutsch. Ing.*, vol. 69, 1925, p. 1169, Figs. 14 to 21). For steam boilers and other pressure vessels they should be rectangular, when they will have the requisite adhesive power, even if the welding of the seams is not quite free from defects.

MANUFACTURE OF AUTOGENOUSLY AND ELECTRICALLY WELDED BOILERS AND OTHER PRESSURE VESSELS

One of the simplest problems in constructing pressure vessels is that of joining a cylindrical shell securely to two heads, which involves one longitudinal and two circular seams. The heads must be provided with a cylindrical prolongation or flange or skirt. Although this is well known, there are those who still believe at times that they can dispense with flanges or skirts. The fact that



Figs. 35 to 53. Various methods of welding longitudinal seams electrically

such joints are dangerous is evident from explosion statistics. The flanges or skirts must also be sufficiently broad. The best contour for the heads is a circle; the next best an ellipse, a ratio of 2:1 of the semi-axes being sufficient.[7]

In autogenous welding the seams are generally only welded on one side, for the seam and neighboring zones of the plate suffer if repeatedly heated. For the joint rarely any other form than the V-shape is considered. The seams are thickened on the outside as much as possible. If it is desired to reinforce the longitudinal seam by means of straps, they must be welded on electrically.

In electric welding the seams may be welded either on one or on both sides, as the seam does not suffer from additional heating due to welding over a welded seam. For thin plates the V-shape of seam is used and for thick, the double V-shape.

[7] See "Uber Festigkeit elektrisch geschweisster Hohlkörper," pp. 53, 61 and 111, and *Zeit. Ver. Deutsch. Ing.*, vol. 69 (1925) p. 155 and p. 367, also vol. 70, p. 163.

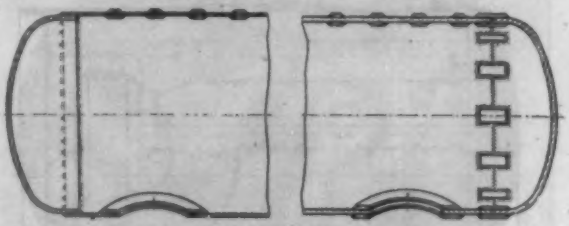
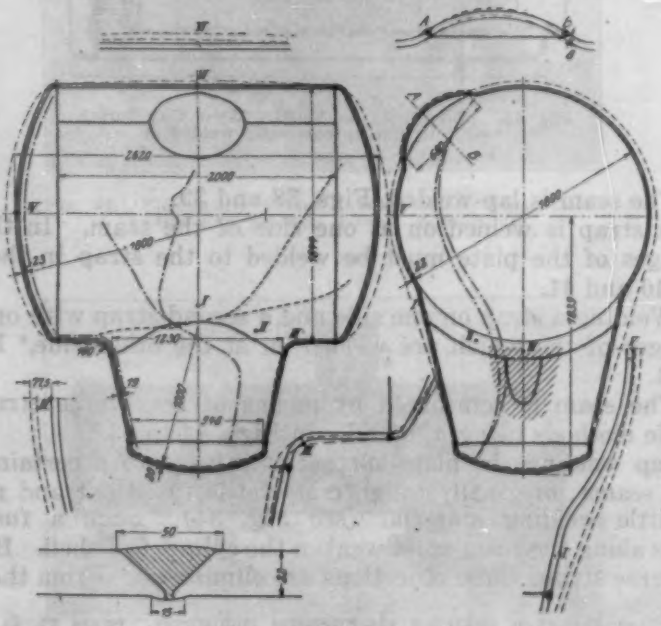


Fig. 54. Two methods of electrically welding a pressure vessel



Figs. 55 to 62. Pressure vessel welded autogenously by Sulzer Brothers A-G., 1919

The seams of a pressure vessel can be welded on both sides only if the interior of the vessel is accessible; but longitudinal shell seams are always accessible on both sides, because the shell may be welded by itself.

A longitudinal seam may be welded electrically by the following methods (see Figs. 35 to 53):

1. The V-shape seam, is welded only at the open side, Fig. 35.

2. The seam is welded on both sides, i.e., the V-shape is subsequently welded at the root, but with thick plates double V-seams are necessary, Figs. 36 and 37.

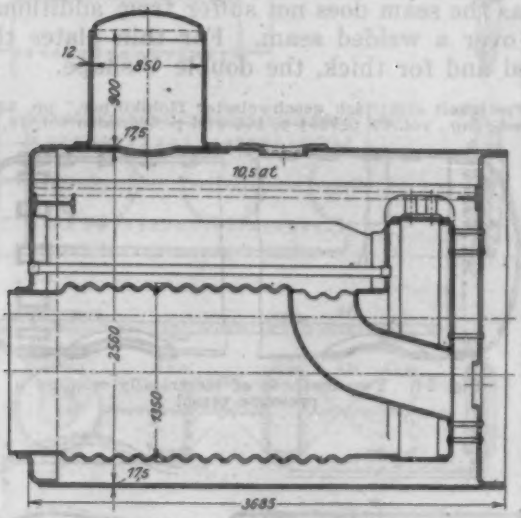


Fig. 63. Boiler built by Escher, Wyss Co., Zurich, with king flue autogenously welded in

3. The seam is lap-welded, Figs. 38 and 39.

4. A strap is welded on at one side of the seam. In this case the edges of the plate must be welded to the strap in the joint; Figs. 40 and 41.

5. Welding a strap on one side and a second strap with openings, the edges of the which are welded on at the other side,[8] Figs. 42 and 43.

6. The seam is reinforced by means of transverse straps, the possible methods being *a*, *b* and *c* in Figs. 44 to 53.[9]

In lap welding the plate surface is injured to a certain extent at the seams; originally tough material is fused out and replaced by brittle welding material (see Fig. 34). Such a fusing-out process along the seam must weaken the cylindrical shell. By using transverse straps these objections are eliminated. From the stand-

[8] See "Uber Festigkeit elektrisch geschweisster Hohlkörper," pages 53, 61 and 111, and vol. 69 (1925) p. 155 and p. 367, also vol. 70, p. 163.

[9] German Patent No. 377,066.

point of elasticity the arrangements in Figs. 47 to 49 are free from objection, provided the transverse straps are not too far apart. Seams in plates of considerable thickness may be reinforced in this manner. The arrangements shown in Figs. 44 to 46 are only applicable to thin plates (0.8 to 1.0 cm.). In those of Figs. 50 to 52 parallel and transverse straps may be welded on simultaneously. The transverse straps then neutralize the bending stresses caused by the parallel ones. In the case of cylindrical shells, which are circular at the longitudinal seam, the transverse straps prevent the appearance of dangerous bending stresses by increasing the moment of resistance.

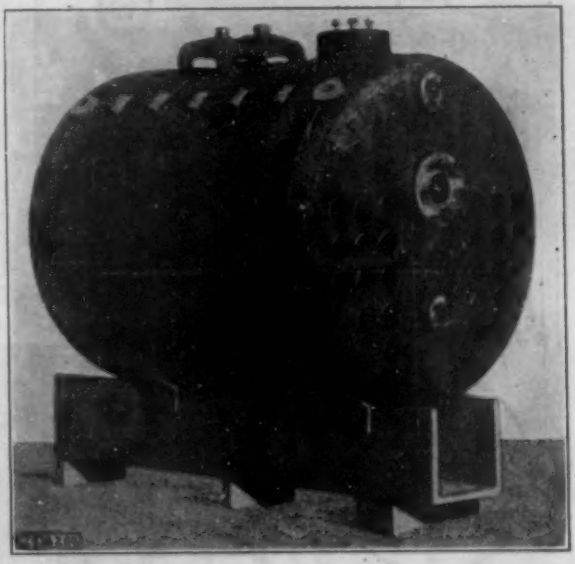


Fig. 64. Electrically welded tubular boiler, Swiss Locomotive and Machine Works, Winterthur

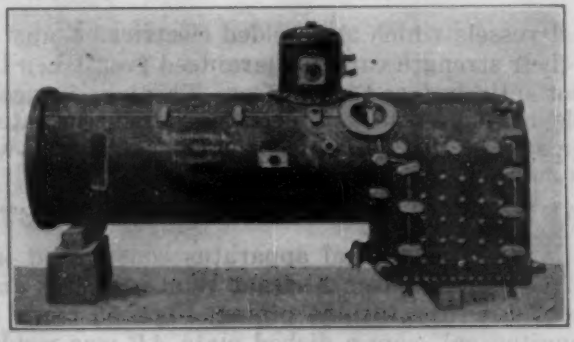
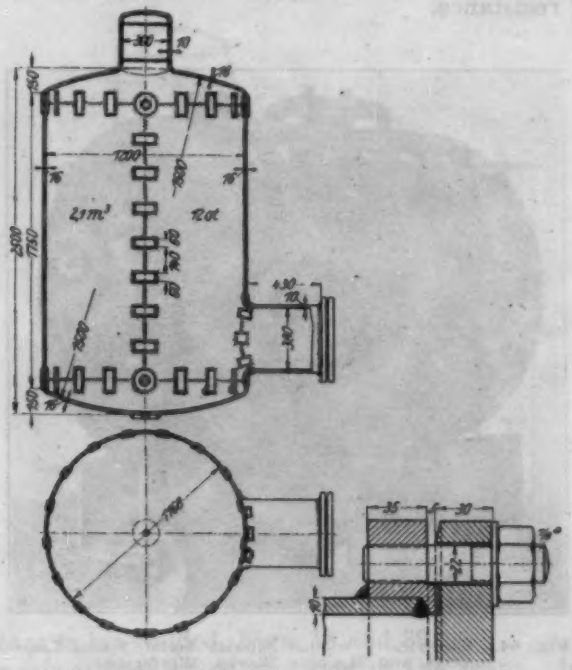


Fig. 65. Boiler for a steam roller welded electrically by the Swiss Locomotive and Machine Works

The distances between the straps as shown in Figs. 45, 48 and 51 may be determined by taking into consideration the shearing stresses that arise in the plate of a cylindrical shell as soon as the tangential stresses are partly taken up by the transverse traps.

Circular seams may also be welded by the methods shown in Figs. 35 to 53; but for circular head seams methods 4 and 5 are rarely employed in practice, because usually the heads do not have flanges of sufficient width (see Fig. 54). If a vessel is not accessible inside, then only seams like that of Fig. 35, with possibly straps welded on one side, are practicable.



Figs. 66 to 68. Electrically welded boiler designed to employ electric heating and built by Wartmann, Vallette & Co., Brugg (Switzerland)

Cylindrical vessels which are welded electrically must be so designed that their strength can be guaranteed even when the welded seams are not entirely free from defects. This may be accomplished by the employment of transverse straps. In thick plates circular seams may also be thus reinforced; for thin plates lap-welded circular seams suffice (Fig. 54).

BOILERS AND OTHER PRESSURE VESSELS CONSTRUCTED

A rather large experimental apparatus constructed in 1919 in the shops of Gebrüder Sulzer A. G. at Winterthur, is an autogenously welded T-tube for turbine piping, Figs. 55 to 62. Midway along the longitudinal seam a dished plate *AB* was welded in, the behavior of which under high pressure was to be observed.

In the hydraulic test permanent deformations appeared which are indicated by broken lines.

At a pressure of 68 atmos. a small crack appeared at point III.

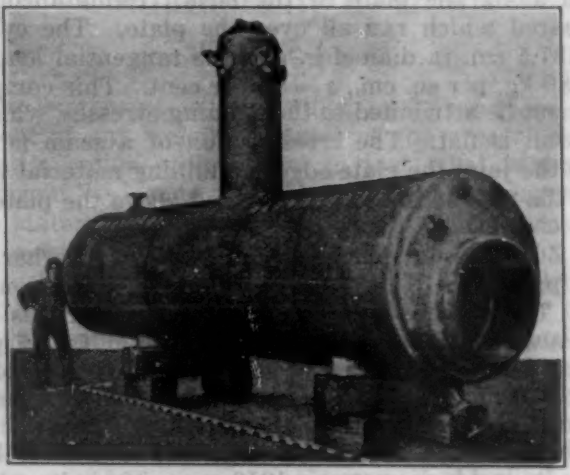
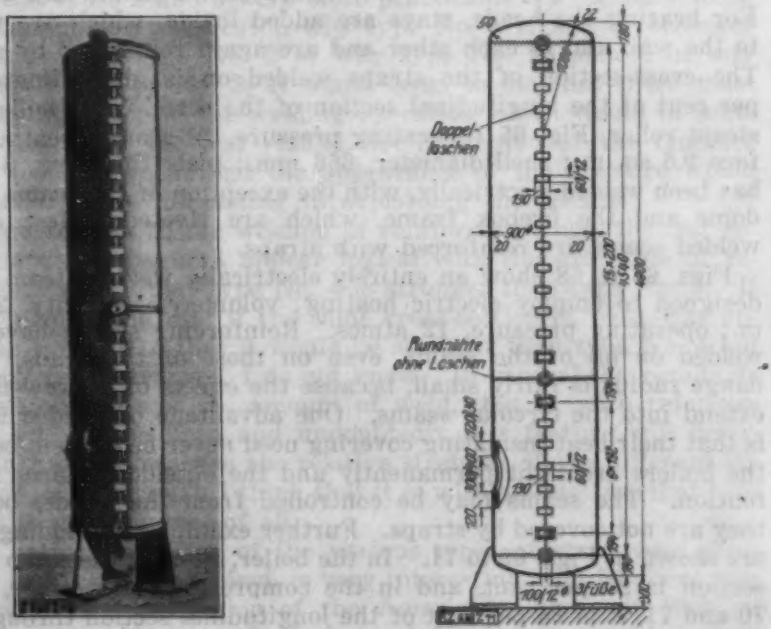


Fig. 69. Electrically welded cornish boiler built by the Swiss Locomotive and Machine Works. Heating surface, 40 sq. ft. M.; operating pressure, 13 atmos.



Figs. 70 and 71. Compressed-air receiver built by the Swiss Locomotive and Machine Works. Capacity, 3 cu. M.; operating pressure, 30 atmos.

Doppellaschen = Double straps
Rundnähte ohne Laschen = Circular seams without straps
Füsse = Feet

Up to this pressure the container had remained tight. A triangular piece of plate was then welded in, see Fig. 60. During the third test a large crack appeared at 70 atmos. which started from point III and ran along the plate of the head. Simultaneously other cracks appeared which ran all over the plate. The cylinder expanded to 187.5 cm. in diameter, and the tangential load on fracture was 2980 kg. per sq. cm., $z = 83$ per cent. This comparatively low figure must be attributed to the bending stresses, which appear where the wall is flat. The cross-section of a seam is shown in Fig. 62. In the joint the plate edges and filling material were hammered until the root of the joint projected above the plate surface; it was then chipped off.

On Lake Zurich four marine boilers built by Escher, Wyss & Co. and equipped with King flues have been in operation for thirteen years. These tubes were welded up in water gas or in the fire, but were welded autogenously into the boiler (see Fig. 63). So far no defects have been noticed. The seam at the top of the firetube, however, is under bending stress, because the cross-section of the firetube is not complete at that point.

Fig. 64 shows a small tubular boiler that was entirely welded electrically. Its inside diameter is 1010 mm.; inside length between heads, 1250 mm.; thickness of plate, 10 mm.; operating pressure 8 atmos.; heating surface 10 sq. m. The longitudinal seam is reinforced by straps which are welded on the inside and outside. For bracing the heads, stays are added inside, which are welded to the wall and to each other and are again reinforced by straps. The cross-section of the straps welded on is approximately 50 per cent of the longitudinal section of the seam. The boiler of a steam roller, Fig. 65 (operating pressure, 12 atmos., heating surface 9.5 sq. m.; shell diameter, 656 mm.; plate thickness, 8 mm.) has been welded electrically, with the exception of the seams of the dome and the firebox frame, which are riveted. Most of the welded seams are reinforced with straps.

Figs. 66 to 68 show an entirely electrically welded steam boiler designed to employ electric heating; volumetric capacity, 2.1 cu. m.; operating pressure, 12 atmos. Reinforcing straps have been welded on all of the seams, even on those of the heads, whose flange radius is fairly small, because the effects of narrow flanges extend into the circular seams. One advantage of welded boilers is that their heat-insulating covering need never be broken, because the boilers are tight permanently and the outside requires no attention. The seams may be controlled from the inside, because they are not covered by straps. Further examples of welding work are shown in Figs. 69 to 71. In the boiler, Fig. 69, the strap cross-section is 25 per cent, and in the compressed-air receiver, Figs. 70 and 71, it is 28 per cent of the longitudinal section through the unthickened longitudinal seam.

All of these pressure vessels have been welded with direct current and with best English wound electrodes.

Discussion of Paper on Autogenously and Electrically Welded Boilers and Containers by E. Hohn

W. L. WARNER†

When the statement is made that one process of welding is most efficient of any welding process of the present day, there is surely some question with regard to just what is meant by the word "Efficient." I note that in the second paragraph of this paper, the statement is made that the water-gas process of welding is the most efficient process of today. I am at a loss to understand just what this statement means. I would take it to mean that any thickness of plate could be welded by this process and that with some thicknesses of plate, it is impossible to weld by any other process. This seems rather strange and I would like to have an explanation of why this is so. This situation does not seem to prevail in this country.

With reference to the tests of welded flanges, the apparatus used to determine the strength of the specimen is indeed very ingenious. However, it does not appear to me that types 1 and 20 as shown in Figs. 1 to 6 are very practicable. It would seem to me that types 2 and 3 were more practicable for ordinary work and I cannot find any reason why type No. 1 should be stronger and better than type No. 2 or why type No. 20 should be any stronger than type No. 3. It would seem to me that there must be some difference in the welding operation which would in some way account for the test results. A discussion of the fracture of the test specimens and the appearance of the fracture would be probably very interesting in explaining the results.

With reference to the welding of reinforcing rings, the test results shown on page 13 appear logical with the exception of result which shows that type No. 4 is stronger than type No. 5. It would seem to me that if the same cross-section of weld was applied on type No. 5 that it would be stronger than type No. 4 but just how much stronger, I do not know. In general the results do not give any idea of the amount of weld, that is, with reference to the size of the bead and undoubtedly this feature will determine in a great measure the relative strength of the different designs of joint although I think that it is without question that type No. 23 is the strongest of all.

The entire discussion of the various types of strap weld illustrated in Figs. 35 to 53 incl. is very interesting, and I believe that the proposed investigation of the American Bureau of Welding and American Society of Mechanical Engineers should include some of these features in their program of tests. However, there

†Industrial Engineering Dept., General Electric Co.

is one thing in connection with this report which strikes me very forcibly and that is the part that says so much with regard to electric arc welding as to where and when it should be used and yet the number of test samples which are shown in the various tables is very much smaller than the number of autogenous welded samples. For this reason, I do not see how anyone could definitely state that electric arc welding is better for some things than gas welding, especially since in many cases only one electric welded specimen was tested as compared with a dozen or more gas welded specimens. It appears also that tensile, bending and impact tests which were made in 1923 and which are listed on the first page of this report state that a great number of the samples were welded using the Quasi-arc electrodes and yet when we come to consider the welding of flanges and reinforcing rings and the other features of this investigation, we do not find very many electric welded samples. We find also that the examples of welded boilers which are given in the latter part of this paper are, in the majority, electric welded, and only two of the seven illustrations given have any gas welding done on them.

It appears to me, therefore, that this investigation while excellent in the diversity of experiments and ideas tested, is rather unbalanced in that it includes a majority of gas welded specimens and only a few electric welded specimens.

This appears to me to be one more important reason why the proposed investigation of the American Bureau of Welding should be very broad and thorough in its scope. In addition to this, all of the details of welding and preparation of the samples should be shown so that anyone reading the report can understand why certain conclusions were drawn and then if necessary, draw his own conclusions contrary to those of the committee if the test results should warrant this procedure.

Comments on W. L. Warner's Remarks Given Above

H. L. WHITTEMORE, Bureau of Standards

I agree with you that the conclusions are not justified by the data submitted and that the number of electric welded specimens is insufficient. It may be, however, that many more specimens were tested than are reported in these articles. I am at a loss to know what is meant by the water gas process of welding and why it should be so highly recommended.

It seems to me that in the tests of welded flanges No. 1 should be much stronger than the other methods of welding the pipes to the shell. In No. 1 you have a straight tensile pull on the weld. The bending where the shell and pipe meet is taken by forged metal. In Nos. 2 and 3 the severe bending stresses come in the weld metal. Any deformation may result in cracks which will decrease the ultimate strength. We know that when dished heads are welded to the shell there is an advantage in having a skirt on the head so that the weld is back several inches from the knuckle.

I agree with you, in the main, on the welding of reinforcing rings. The cross-sectional area of the bead, of course, should be given to allow the strength of the weld to be estimated.

I am glad to know you agree that the discussion of strap welds is interesting and that this German report should be carefully studied before our investigation is started. Personally, I do not believe that the reports I have seen of the German investigations justify us in adopting their conclusions. These reports do, however, suggest variables which should be studied in our investigation if we expect to obtain the best form of welded pressure vessel.

My purpose in using the German tests in my paper before the American Bureau of Welding was to call attention to the necessity for trying everything which was proposed and eliminating the unsuitable methods of fabricating tanks.

Discussion of Paper on Autogenously and Electrically Welded Boilers and Containers by E. Hohn

JOHN J. CROWE*

There are several points I desire to call attention to in the paper by E. Hohn on "Autogenously and Electrically Welded Boilers and Containers."

It is stated that "of the personnel employed in the test, some were beginners; today probably better results would be obtained." This statement of itself vitiates and casts a serious doubt on all of the results quoted. In this country only experienced welders are entrusted with the responsibility of welding pressure vessels and work done by beginners should not be used as a standard of comparison for various methods of welding, or for the setting up of standards to be used by engineers in the design of pressure vessels.

In table No. 1 the average tensile strength of the 67 bars autogenously welded, is 2.81 tons per sq. cm., or 39,800 lb. per sq. in. This is an exceptionally low value for welded joints and would indicate that inexperienced welders had been used. The average tensile strength obtained on several hundred coupons welded by several embryo engineers in our laboratory, using low carbon steel rod, was well over 50,000 lb. per sq. in. The welds were of the V type (type 35), made from one side only and machined to size before testing, whereas the paper states that the figures quoted are for reinforced welds. When alloy steel welding rod is used the results obtained are appreciably higher and in many instances are over 65,000 lb. per sq. in.

*Engineer in Charge of Apparatus Research & Development, Air Reduction Sales Co.

There is no basis for the statement that electrically fused iron adheres better than autogenously fused iron. In all cases where the break occurs through a weld properly made, the path of the fracture is in the added material, and not where the added material has been joined to the parent metal. This last only occurs in improperly made welds of either type—gas or electric. If the author (E. Hohn) has had autogenously fused metal separated from the parent metal, it is a clear indication that proper penetration has not been obtained.

Of the three variables studied, that is, tensile strength, bend (ductility), notch bar impact (resistance to shock), the autogenous welds gave the better results in all but the tensile tests, but the author has evidently disregarded these facts in drawing his conclusions.

In table 6 the mean forcing off pressure of 60 rings, autogenously welded, is 50.3 tons as compared with a mean of 47.4 tons for four electrically welded rings, and again in table 8 the autogenous method as judged by the results given, is greatly superior to the electric method for the purpose of welding plates perpendicular to each other.

It would appear from the paper that the autogenous method has been employed for welding a number of pressure vessels and that they have in addition to remaining tight up to a pressure of 68 atmospheres, 1000 lb. per sq. in. have successfully stood the test of time and service which is the real criterion by which any method must eventually be judged.

In view of the fact that the welds were made by inexperienced operators, the paper can hardly be considered as a contribution to the art of welding and fades into obscurity in the light of the most excellent work done along similar lines at the Bureau of Standards, under the auspices of the American Bureau of Welding.

Discussion of Autogenously and Electrically Welded Boilers and Containers

S. W. MILLER†

It is very unfortunate that the figures were not translated into English units, because as they stand, they mean nothing to the vast majority of those interested in the subject.

It should be remembered in reading this article that the word "autogenous" is used to refer to gas welding in counterdistinction to the word "electrical," which refers to metallic arc welding.

In the limited time available I can only point out a few serious matters. The statement that, "electrically fused iron adheres better than autogenously fused iron" is without basis in fact, as a molecular union is produced in both cases, and more cannot be done.

†Consulting Engineer, Union Carbide and Carbon Research Laboratory.

There is no difficulty in gas welding mild steel plate so that test pieces will always break outside the welds.

It is stated that in autogenous welding, welding both sides cannot be done very well. This is also contrary to the facts. Statement is made that double V joints can only be made in thick plates ¾ in. thick or thicker. This is another statement that is not borne out by common practice.

A very significant statement is made as follows: "Of the personnel employed in the tests, some were beginners, but today probably better results would be obtained."

Many of these tests were made in 1914, others in 1921, still others in 1923. It certainly seems futile to compare the results of tests made twelve years ago with present day practice, and the use of beginners would certainly seem to have been a mistake, unless their results were segregated and not included in the averages. Such an inclusion destroys the value of any comparison and does not give a true idea of the possibilities of welding.

The use of straps welded across the seams is not considered in German practice a desirable thing. This is in accordance with the statement of Dr. Max Fuchsel, chairman of the Welding Committee of the German Engineers Society at Berlin. This statement was made at the last meeting of the American Welding Bureau by Dr. Fuchsel in commenting on this article. He also stated that it is the endeavor of the German Welding Engineers to produce a weld of such good quality that it is not necessary to use straps. He also said that in Germany one of the serious objections to the strap seam was the stresses which were undoubtedly set up due to the local heating.

I would also point out that there is a wide difference in design stresses in the welded pressure-vessels shown. In the case of Fig. 66, the stress at working pressure is 8000 lb. per square inch. In Fig. 64 the working fiber stress is about 7200 lb. Fig. 65, the working fiber stress is 6400 lb., while in Fig. 70 the working fiber stress is 9400 lb. per square inch. If these are typical examples of design, two things seem apparent:

First: There is no unanimity of opinion as to proper design stresses for strap construction.

Second: That as far as the figures go, the fiber stresses are so low as to indicate lack of confidence on the part of the designers as to the quality of their welds and the validity of their designs, even with the theoretically greatly increased strength due to the straps. I would also point out that from a commercial point of view the application of straps is impractical because of the greatly increased cost, there being from two to four times as much welding in the strap seams shown as there is in a straight welded seam.

I shall take a later opportunity to make further comments on this article because there are other points that should be covered.

Discussion Technical Papers Presented at Annual Meeting American Welding Society, April, 1926

Discussion—"The Design of Welded Joints," by E. E. Thum, Engineer of the Linde Air Products Company.

Mr. L. H. Burkhart, Chief Engineer, Struthers-Wells Co.: I would like to inquire if the hoppers were actually made that way or designed theoretically?

Mr. E. E. Thum, Manager, Publicity Dept., Linde Air Products Co.: This job, blue print of which I sent around, was erected in 1908. It has occurred to me many times since (I was on that work as instructor of steel draftsmen) that the design had so many possibilities of advantages that I merely introduced it theoretically at the present time.

Mr. L. H. Burkhart, Chief Engineer, Struthers-Wells Co.: From a manufacturer's standpoint I would find some difficulty in fabricating that hopper from one plate. Difficulty would be experienced in bending along the radial lines; then there is considerable waste around the outside, because the plate would have to be cut from a rectangular plate and all the outside wasted. The cheaper construction would be to make it in four plates with four welds along the radial lines. Then the plates could be cut from two rectangular plates with the sides reversed, making practically two rectangular plates from which the sections would be cut.

Mr. Thum: I agree with you. Our experience indicates, however, that rather than a corner design, the sheets should be bent and welded in the center.

Mr. Burkhart: It might be made with two bends and two welds which would be a compromise for welding and bending.

Mr. J. H. Edwards, Asst. Chief Engineer, American Bridge Co.: I would like to ask if the unit stresses given in the kiln were static stresses, or if in figuring the stresses the kiln was considered in motion and the material which it was carrying as falling a certain distance?

Mr. Thum: I will ask Mr. Greene to answer that. He made the tests.

Mr. J. W. Greene, Welding Engineer, Linde Air Products Co.: The question raised is as to whether the stresses were static or dynamic. The speed of revolution of the kiln was taken as one revolution every minute and the stress determinations were made when revolving at this speed. Static and dynamic stresses were taken into consideration. The revolution of the kiln is so slow that the dynamic stresses are very negligible, at least it checks so closely to theory as to the static stresses, that I doubt if they vary in magnitude at all.

The kiln stresses were made, of course, under load. They were not made under hot conditions but the load on the kiln was 90 per cent of the load that it would be under actual operating conditions.

Mr. Edwards: It might be of interest to say that the company with which I am connected for years has not permitted the use of welded chains in any of its field work. Our chains are made in our own shops under about as good conditions and procedure as we know and can expect, and while we do use them in the shops and watch them very closely, they are always annealed under supervision, but our field directors are never permitted to use chains. We have substituted in place of chains, due to many accidents which we have had, wire rope slings.

Discussion—"Welding in the Design of Industrial Power Piping," by L. J. Sforzini, Engineering and Maintenance Department, Eastman Kodak Company.

Mr. R. C. Wickersham, The Koppers Co.: We are users of considerable quantities of large diameter pipe for low pressure gas work and have been specifying the single V weld. Our experience has been that the single V is satisfactory in operation but is very easily cracked in the welds, due to handling when loading or unloading, and also due to strains set up in pulling the pipe together when making joints. This seems to indicate to us that the single V weld is either too hard and brittle to stand shocks, or that strains are set up when welding which do not allow much additional tensile pull before breakage occurs.

We have been advised that the V weld should be welded outside and then inside, or that it should be butt-strapped as shown in figure three. This is at present a problem with us on which we are not at all clear.

Mr. W. D. McKay: I would like to ask what is being done to take care of shrinkage by hammering and annealing and also what is being done on welds on material above say, five-eighths of an inch thick?

Mr. L. J. Sforzini, Eastman Kodak Co: My paper is confined to piping and the greatest thickness of a commercial pipe is three-eighths of an inch. I am not familiar with anything in piping as heavy as five-eighths inch. As I stated in the paper, my remarks deal with piping used for pressures under 300 lb. per square inch. It is all confined to standard commercial pipe which is three-eighths of an inch thick all around. I will leave the answer to that question to somebody who is a practical welder.

Mr. S. W. Miller, Consulting Engineer, Union Carbide and Carbon Res. Lab.: I might give a little information in that connection. In the paper that was read by Mr. Thum, you will remember that the shell was five-eighths of an inch thick. Those welds were not annealed. The procedures in the welding of them were such as to practically eliminate stresses. Relieving stresses de-

pends very largely on the way the pipes are put together and the methods of welding.

The pipe material is very low carbon steel and it is quite ductile and with a little elongation. The result is that the stresses are taken up by that ductile material. If such material is tool steel there would be considerable difference. It is perfectly possible, and has been found so by tests, to relieve, if desired, any stresses that may exist by simply heating the whole weld uniformly to a very dull red heat.

Mr. G. O. Carter, Consulting Engineer, Linde Air Products Co.: Mr. Miller left out one thing that may be important in piping. Toward the end, when within about an inch of the finish of the weld, the pipe is heated an inch and a half ahead so as to bring the old weld to a red temperature before you complete the weld. By so doing any tension stresses on the completed weld of the last inch are eliminated. If this is not done there are apt to be small checks that will run three-quarters of an inch in length.

Mr. J. W. Owens, Director of Welding, Newport News S. B. & D. D. Co.: The shape of the piping being circular in form permits the relief of these stresses. Stresses of this sort are usually very much lower in cylindrical vessels.

Mr. Sourwell: I would like to call attention to the fact that the names of the authors in the paper on Expansion of Piping are Sanford instead of Sabin and Crocker. I would like to point out further that figure three, showing a butt weld reinforced with a sleeve, might involve some danger in high pressure work. I would rather see that butt weld uncovered by the sleeve. Then if any leak developed it could be corrected. Otherwise, the covering of the sleeve might introduce corrosion trouble.

Mr. Sforzini: In answer to the gentleman's question, would say we have used that type of weld for steam and brine. The brine pipe has been in service as much as three and four years and no trouble has been experienced. As to whether later trouble will develop or not, I can't say.

Mr. Carter: Experience shows that the plain butt weld almost never fails, or if it fails the conditons are easily accounted for. Covering seems to be a needless expense. I don't doubt but what good results have been obtained with the extra sleeves.

Mr. Sforzini: I pointed out in my paper that there is a difference between steam piping and fluid piping. Steam piping, after being placed in service, becomes hot, and you have three-quarters of an inch of expansion for every 100 feet of length and every 100 degrees change in temperature. There have been cases on record, one case in particular, as I pointed out in the paper, where the V butt weld has failed. I don't believe there are any cases on record in steam piping where the sleeve joint has failed. I have here a picture of a weld in my paper showing just how it failed.

Mr. Carter: The piping that I was mentioning is twenty-inch

piping, taking the gas directly off natural gas compressors, where the temperature is very high and it is under the same temperature stresses that we are considering in piping, with which I am quite familiar. I believe that trying to depend upon the covering gets us into bad habits of slacking up on the training of men and making sure that the men are capable of welding. We have never known of a case of failure where a proved man did the work.

Mr. P. A. L. Maurhoff, Oxweld Acetylene Co. (Philadelphia): Along the line mentioned up at Columbus Circle, where pipes had welded sleeves, last summer, down in Philadelphia, there was a very nice job made in carrying the gas mains across Broad Street where the subway is now being constructed. Towers were erected 100 to 125 feet apart. Suspension cable slung between, and eight, twelve and fourteen-inch gas piping carried across, supported by hangers from this suspension wire. Provision was made to guard against wind stresses. This was a plain, butt-weld carrying low pressure gas, but from observation and from what information I can get, there has been no trouble from leakage. Even with the outriggers I have noticed on windy days there was considerable vibration in that pipe. The job was put in late last summer and went through a very cold winter and is still there in good shape.

Mr. Keckstead: In regard to the pipe at Columbus Circle, I think the speaker referred to the butt-welded pipe with sleeve reinforcement over it. That is a pipe that has the sleeve welded on it but the butt of the pipe is not welded purposely to eliminate all set-up stresses between the circumferential welds.

Another speaker said that there would be no stresses in cylindrical vessels. That, in my opinion, refers only to a longitudinal seam where the curve of the sheet will take care of expansion and contraction, but not in circumferential joints. A circumferential joint welded is, in my opinion, more dangerous than welding a flat sheet which has the possibility of warping to take care of the stresses. A round cylinder that is welded is absolutely the most rigid construction and will not give at all and all stresses must be taken up in the weld itself.

We made several actual tests of set-up stresses in pipe lines and we have found that butt welds invariably set up stresses, at least with an electric weld. An oxy-acetylene weld will not set up stresses if the whole seam has an equal temperature all the way around.

If, for instance, a pipe of good character, twelve inches or more, is welded, half way around, we will say, and allowed to contract over lunch or at night and is continued the next day, you cannot possibly prevent any set-up stresses. The same holds true with an electric weld to even a greater degree.

The suggestion of butt-welding pipe first and then reinforcing by sleeves is, in our opinion, exactly contrary to the theory of stresses involved. If the butt weld is first welded, assuming that it has no set-up stresses in it and the sleeve is then put on after welding

along one edge, there is no possibility of contraction or expansion, and the minute you weld the second edge of the sleeve, you either will have an expansion or contraction strain in one of the three welds, to the extent of being up to the breaking point.

One gentleman referred to a pipe in Philadelphia not having shown any signs of leakage for a year or so. Still that pipe may be up to its elastic limit and possibly break at a hammer blow. One can weld a sleeve joint in such a way that it takes almost any load but is practically zero in efficiency at the shock of a hammer blow.

Mr. Owens: Mr. Chairman, the last speaker slightly misinterpreted my statement. I meant that the stresses in cylindrical vessels are less than in butt joints in which the plates are on the same plane and even then those stresses of the same plane are of varying degrees, depending upon their rigidity. The stresses also in a circumferential seam while there are relieved to a certain extent by the end of those cylindrical walls. I have deposited metal on the outside of a cylinder and the dimensions inside before and after welding have been different. That is, after welding, they have been less, showing that the walls of the vessels have been pulled in and relieved of those stresses.

Mr. Stone, New Jersey Zinc Co: I have been very much interested in this discussion this afternoon because I have had something to do with power plant piping and I had another little problem put up to me recently—submarine piping. In connection with the power plant piping, I merely want to reinforce what the speaker said about the importance of calculating the stresses in pipe bends, especially in large sized pipe bends. As the diameter of the pipe increases its resistance to bending increases very much and the stresses set up by bending it increase very much. So that the larger your pipe, the more careful has to be the design of it and the calculation of the stresses that are going to come on the welds.

I have been making a search recently of methods of laying underwater pipe and I find a good many methods, including that of welding steel pipe together and dragging them across the bottom of streams or out to sea. I find that down at Tampico, Mexico, pipe lines have been welded and dragged out to sea to a distance of about a mile on the sea bottom, just towed out to sea. The joints in that case were long threaded sleeves, recessed and welded on either end of the sleeve. I find that butt welds have been dragged across streams without any sleeves and apparently no fracture or leakage has resulted in the rough treatment of the pipe. The pipe was welded perfectly straight and then allowed to sag down and take the contour of the stream bottom.

What I don't find, and what would interest me very much, is the expected life of those welds, if not coated, in salt water. I was speaking to a representative of the Reading Wrought Iron Pipe Company today and he spoke of the wrought iron pipe that had been on the sea bottom for twenty-six years, with screwed couplings, that is, the pipe had lasted twenty-six years on the sea

bottom. It was three-eighths walls. Recently that has been replaced with a pipe with threaded sleeve, couplings welded at either end of the sleeve.

Our experience with pipe on Long Island in gas works practice, etc., has been that the welds rust, at least above ground, much more rapidly than the pipes themselves, and I was wondering what the expectation of life of a welded joint under water would be. I think that is a good thing to take into consideration in planning a submarine installation. You may have pipe that will itself last for twenty-six years but, welded together with butt weld, it won't last more than eight or nine years. I am wondering whether any of the members of the Society can give me any information on that topic.

I was very much interested in what one of the speakers said about the stresses set up by the triple-welded joint, that is, the butt joint and the sleeve weld, welded on each end. It seems to me you have the same kind of stresses when the pipe is threaded. I wonder if that would be so. In that case I should think that would be the worst possible form of joint to make for a pipe that was going to be dragged along the sea bottom or the bottom of a stream. I would be very glad to hear from any member of the Society that can give me any pointers on that.

Mr. Owens: I don't think there is any stress in the case of a threaded joint. I think that joint is perfectly safe and resistant to corrosion. My experience has shown that there is no appreciable difference between the corrosion of the plate in sea water and corrosion of the weld. In welds that have been under my observation for several years, I have seen no difference between the two.

President A. G. Oehler, Editor, Simmons-Boardman Pub. Co.: Can you give us any reason why, in your opinion, the stresses should be less in the case of the screwed joint where it is also welded than it would be in the other type of joint described previously?

Mr. Owens: I don't say the stresses would be less. I think they would be practically the same.

Mr. R. J. McKay, International Nickel Co.: We made some retorts for chemical work. The life of those retorts was about six months, but I noticed that the weld didn't corrode away as much as the plate. The plate was a half-inch thick.

Mr. Miller: I think it will be found that if the cases are collected in which corrosion has been a vital factor, you can get anything you want. We get complaints that the weld corrodes more rapidly than the base metal does. The next fellow comes along and says the base metal corrodes before the weld does, another states they both corrode equally and the third says neither corrodes at all.

If any of you have paid any attention to the matter of corrosion, even in riveted vessels, you will find that the same troubles exist. Sometimes the rivets corrode; sometimes the butt strap corrodes; sometimes they both corrode equally and sometimes they don't

corrode at all. Also, those of you who have attempted to study the matter of corrosion, know that a bibliography of the literature on corrosion occupies a volume about three-quarters of an inch thick containing some 500 pages and with nothing more in it than a simple reference to the articles that have been written on corrosion.

During the war the merchant marine corporations took up that matter as far as seawater was concerned and Commander Knox of the Norfolk Navy Yard fastened to the stern of a number of naval vessels samples of welds. Of course, the armistice came along and spoiled the test but up to the time that the test was abandoned there wasn't any noticeable difference in the corrosion of steel plates and the welds.

I don't know that anybody can determine what is going to happen in any particular case or predict in regard to corrosion. The only thing to do is to try it. As far as the apparent conditions of the test are concerned, absolutely contradictory results were obtained and the only thing I can say would be if you want to find out what is going to happen, try it. I might also say that welding hasn't been in service twenty-six years, so nobody can give comparative figures.

Mr. Wm. Schenstrom, Electric Welding Co. of America: With regard to corrosion and the many different results that have been reported, isn't it possible that the character of the weld made has something to do with it? Electric welding can, under circumstances, be somewhat porous, giving a larger surface exposed to chemical action. For instance, in shipyard work referred to, where it is exposed to the action of salt water, I believe that the methods of carrying out the welding may have something to do with it. Of course, oxy-acetylene welding has less pores.

Now with regard to the stresses set up in the joints of piping, I have observed in three-eighths inch wall thickness and half-inch wall thickness of large diameter pipe, welded by the electric arc process, that set-up stresses have been such that one could go along the joints one after another and if one hit them hard enough with a sledge hammer, cracks would show up along the circumferential joints.

I have seen long pipe, thirty-five or forty feet long, fall off a truck and show long cracks right in the middle of the weld of the circumferential joints and I would ascribe those cracks to the set-up stresses in such a butt-welded joint.

Mr. Greene: With reference to the set-up stresses in joints, I have been trying to determine what they are and, as Mr. Owens brought out, as the weld progresses, each cooling increment of course is thrown under tension, but as the next one adjacent to that is deposited it throws the previous section into compression; so as the whole weld is completed the probabilities are that the whole pipe weld is under compression except the last deposited section and, therefore, by extending over your heating a little beyond the finish of your weld, you tend to dissipate to a great extent the tensile stresses that might be set up in the weld.

I think it is also true that in a round pipe you have a greater chance for dissipation of any strains than you would have on a flat plane, because the pipe tends to contract and the diameter tends to dissipate those strains, so I should think that the stresses in a pipe due to welding are a very negligible quantity.

In reference to figure four in this paper on Industrial Power Piping, the author shows a reinforced weld at the extreme bend of the expansion bend for this pipe line. As he brought out, if you determine some of these strains that are set up in a bend, the maximum stresses occur right at that point and are in proportion to the distance from the main piping line. I just wondered if, in this case, it wouldn't be better to have shifted that weld to another point away from that maximum strain?

Mr. Sforzini: That was laid out before Messrs. Sanford and Crocker conducted their research work and was just put there arbitrarily and was to be gone over again.

Discussion—"Design and Manufacture of Horizontal Cylindrical Pressure Tanks," by Mr. L. H. Burkhart, Chief Engineer of the Struthers-Wells Company.

Mr. J. C. Lincoln, President, Lincoln Electric Co.: I want to call attention to what is apparently an error on page thirty-three. Here we have a formula T equals PR over S. You will find that the first formula works out correctly. In the second formula the symbols are given but instead of being a unit stress of 8,000 lb., the formula shows 55,000, and instead of showing the radius of the shell as 24 inches, it is 48 inches. That is an error which should be corrected in the final reprint of the paper.

Mr. J. J. Currey, L. O. Koven & Brother: I would like to ask Mr. Burkhart whether it has been his experience that the butt-welded joint is better than the so-called lap-welded, where you can sink the heads into the rivet construction.

Mr. Burkhart: In some cases it is more desirable to have a smooth interior if a tank is going to be lead-lined, or if the fancy of some designer likes to see the thing smooth, you use the butt joint, as this drawing shows, but in a great many cases a flange is inserted inside of the shell and welded inside and outside, and I don't believe there is any difference in the strength of the structure. It is just a matter of choice.

Discussion—"Design of Welded Joints," by S. W. Miller, Consulting Engineer of the Union Carbide Company.

Mr. Burkhart: While Mr. Miller's formulas are correct and there is no fault to find with them, yet I believe they represent

fictitious accuracy because of the variation in the steel plate which would run from 55,000 to 65,000 lb.

Dr. A. D. Risteen, Director of Technical Research, Travelers Insurance Co.: I have been very much impressed by this paper of Mr. Miller and I just wanted to call your attention to one thing that perhaps might lead you to a better appreciation of the possibilities that underlie a consideration of this kind of formula. Some years ago I was very much interested in the theory of the hook; the ordinary garden variety of hook for hoisting, etc., and I tried to find out something about hooks.

The old, time-honored formula of Grashof for the hook cannot be made to give anything that is remotely realizable in practice. I mean to say, it gives something that is altogether bigger than anything that practice requires. However, it was the accepted formula for a great many years.

Along came Pearson, an Englishman, who is quite an authority on the subject of stresses and strains and the theory of elasticity and he undertook to find out, if possible, what was the matter with that formula of Grashof. The fact that the hook contracted laterally, as any other strip will, when the longitudinal tension is put on it, had not been properly considered. He put forth an alternative theory, which did take that ratio into consideration, and he found that although he got a somewhat more complicated formula, he got a formula that has agreed in all essential particulars with what experience shows is true of hooks.

I realize that what I have said hasn't any direct bearing upon this question of welding, but I thought it might be interesting to you as showing or indicating that perhaps this matter of the lateral contraction, when longitudinal tension is applied, may be of very exceeding importance.

Mr. Lincoln: I have had a recent occasion to get some idea of what the strain was on a pipe that was tested under pressure and I couldn't see but what the first formula was the correct formula to figure the strains in the pipe with a given pressure of water on the inside.

Mr. Miller: The common formula simply takes account of the stress in one direction. It does not take account of the stress that works into it. I was not talking about pipes. If you want to figure the stress on pipe that has open ends, for instance, a penstock, your formula is not the same as these. These formulas are only applicable within the elastic limit. There is no formula known that will give you the stress at the ultimate load. For a pressure vessel in which the ends are closed, the common formula is not applicable at all because it takes care of the stress only in one direction instead of the real stresses that exist in three directions.

Mr. Lincoln: In figuring the stress in a pipe, especially when the pipe is laid in a trench, there isn't much chance for an expansion along the length of the pipe and it would seem to be that the only possible move of the pipe would be an expansion of the pipe

in a diametrical direction so that the fiber stress in the pipe would be proportional to the pressure of the water or whatever the fluid is on the inside.

Mr. Miller: I don't know anything about the friction of the earth on the pipe. We all know that it is impossible to weld rails on a steam railroad. They won't stay there, but it is perfectly possible to weld the joints in street railway rails. The coefficient or the friction on the side of the rails of the earth after it is packed practically prevents any expansion of the rails. The same thing is true of a pipe.

Mr. Burkhart: To further establish Mr. Miller's contention I have tested out horizontal cylindrical tanks where the diameter is equal to the length and before they burst they became practically a sphere. A sphere is the only shape in which there is no stress.

Mr. Houston: I would like to ask Mr. Miller what formula he used for figuring his thickness of the inner shell of a jacketed vessel for a certain jacket pressure?

Mr. Miller: The only formulas that are available on that are based on either Fairbairn's experiments of a great many years ago and a few others that have been made since. I believe in Fairbairn's experiments the largest shells that were used were thirty-six inches in diameter, and probably a quarter or three-eighths of an inch thick. In that case, if the shell is perfectly round and there are no flat spots in it, it is evident that a uniform external pressure will cause no difficulty up to the compressive strength of the material. The difficulty is that we can't form a shell that way and we have no means of knowing the amount of eccentricity or elasticity of the shell, and, therefore, we can't make any calculations.

Mr. Houston: I floundered around for quite a while and at last landed on the formula for the Adamson ring and I applied that to a shell six feet in diameter and eight feet long, working out the thickness of the shell at one inch for 250 lb. test, and all I know about it is that it is satisfactory as a test, but how near right I was, I can't tell.

Mr. C. W. Bates, Philadelphia Electric Co: I think one element that Mr. Miller didn't point out quite clearly enough is the fact that when the thickness of the shell or pipe is sufficiently small as compared with the diameter, the first three of these formulas are identical, and that the fourth one, which I believe includes a little end effect, is identical to the others with the exception of the fact that it is five-sixths. It is only when you come to pipes of the dimension of the old wooden barrel that you dig up occasionally right out of the streets where you have a two-inch hole and a twelve-inch length or something like that, that you get the extreme difference. Mr. Miller shows something like twenty per cent difference there. If you went to the extremely thick pipes you might get even impossible results on some of the formulas and fairly correct results from the last one.

Mr. Miller: I might point out, Mr. Chairman, that these formulas are only applicable to closed end vessels. They are not applicable for guns. Modifications of formulas are applicable but the formulas themselves are not and I think if Mr. Bates will sit down and figure it out he will find that even with a twelve-inch pipe and a quarter-inch shell there is quite a material difference. The National Tube Works made a large number of tests on the bursting strength of pipes of various kinds and they found that the bursting pressure was represented by Barlow's formula better than it was by the common one. As I said before, there is no formula by which you can figure anything that goes beyond the elastic limit.

Discussion—"Arc Welding in Hydrogen and Other Gases," by P. Alexander, Thomson Research Laboratory, General Electric Co.*

Chairman Adams: Approximately what percentage is the cost of the welding process increased by the use of these gases?

Mr. Alexander: I think that the cost of welding could be decreased by using this process, because by supplying a proper hydrogen mixture we increase considerably the speed of welding. Therefore the speed of welding will offset entirely the cost of the gases necessary. At the present time with our very inefficient laboratory operators, I am using something like from thirty to fifty cubic feet per hour. This means an increased cost of welding of something like on an average of fifteen or twenty cents an hour. By increasing the speed of welding by this means, the additional cost will be offset. But it seems to me the greatest advantage of this process will be not in increased speed, but in quality of work.

Mr. Carter: I was going to suggest the use of compressed natural gases in the form of propane. You don't have to put any heating means or gasifying means in it. It comes off at a very steady flow and you get a great deal in cylinders; 1400 lb. of natural gas in a cylinder that is 14 inches in diameter and only 12 inches long.

It looks as though you are going to get a wider heat zone than you do with the present very concentrated electric arc and the minute you do you are going to get into the same difficulties experienced in oxyacetylene welding, and that is the handling of the metal in long seams. In every tank shop in the country you can find a tank they tried to weld and they had trouble with buckling. A great deal of what we have done in the last year is learning the shop kinks of handling the work. Unless I am badly mistaken, you are going to have the same wider heat zone that we had with oxyacetylene. It is my personal belief, however, that all this work is on the correct metallurgical basis.

Mr. Owens: I broached that very question to Mr. Alexander yesterday. I saw immediately that that was the chief disadvantage

*Paper printed in March, 1926, issue Journal, A. W. S.

and Mr. Alexander replied that that is solved entirely by the use of the nitrogen-hydrogen mixture, which gives a very concentrated flame. He also stated to me that the heat was so small that you could put your hand below it; so that the additional heat from the flame does not add any thermal energy to the joints which would cause warping.

Mr. Alexander: Natural gas, in propane alone, will not give good results. Experiments conducted with propane or some other gas always produced, at least in my experience, very brittle welds, but if you mix propane with some other gas, for instance, if you mix propane with carbon dioxide, three volumes of carbon dioxide and one volume of propane, you will get satisfactory results. However, these gases are unsuitable if used separately. When you mix them, the heat of the arc will decompose them. Carbon dioxide will be decomposed into carbon monoxide and oxygen and propane will be decomposed into hydrogen and carbon. If the proportion of these gases is right, the resulting mixture will be carbon monoxide and hydrogen and the welds produced in these mixtures we have found quite ductile.

Resistance of Shells and Tubes to Internal Pressures*

S. W. MILLER†

This matter is possibly of more interest now to mechanical engineers than it has been in the past, because of the strong tendency to increased pressures in many cases. The actual use of 1200 lb. pressure in boilers and the proposal to use 1350 lb. are indications of what may be expected in the future.

I have therefore reviewed the formulas in general use, and made comparisons between them, putting them in somewhat different form from past methods of presentation.

The common formula, so-called, is known to all engineers, and its derivation is obvious. Its usual form is

$$T = \frac{pd}{2t} \qquad (1)$$

in which

T = tangential fiber stress in shell, lb. per sq. in.
p = internal pressure, lb. per sq. in.
t = thickness of shell, in inches.
d = internal diameter of shell, in inches.

It is based on the theory that the stress is the same at all points

*Amplification of paper on "The Design of Welded Joints," presented by Mr. Miller at Annual Meeting of Society, April, 1926, and printed in April, 1926 issue of Journal, American Welding Society.

†Consulting Engineer, Union Carbide and Carbon Research Laboratory.

in the shell thickness, omitting any consideration of the radial and longitudinal stresses.

It is usually supposed to give accurate enough results for shells thin compared with their diameter, and as it is easy to use, it is employed probably more often than the others.

The formula, due to Barlow, is the same as the common formula, except that d is taken as the outside diameter.

It considers only the tangential stress and shows that this varies inversely as the square of the distance from the axis, the basis for the formula being the assumption that the cross sectional area of the shell does not change under pressure. Taking d_2 as the outside, and d_1 as the inside diameter

$$d_2 = d_1 + 2t$$

Substituting this in the common formula and reducing, we have the tangential stress at the inside of the shell

$$T_1 = \frac{pd_1}{2t} + p \qquad (2)$$

and as the stress varies inversely as the square of the distance from the axis, the stress at the outer surface is

$$T_2 = T_1 \frac{d_1^2}{d_2^2} \qquad (3)$$

It is evident that the stress at the inner surface is greater than anywhere else in the shell thickness.

From formula (2) this maximum stress is greater than that from the common formula by the amount of the internal pressure.

By substituting $d_1 + 2t$ for d_2, and the value of T_1 in formula (3), and reducing, we have

$$T_2 = \frac{p}{2t}\left(\frac{d_1^2}{d_1 + 2t}\right) \qquad (4)$$

In formulas (2) and (4) the stresses are given in terms of the inside diameter and thickness, which is rather more convenient for calculations. It is clear that when t is small compared with d_1, the term $4t^2$ may be omitted. This is especially true when t is less than one inch. If this be done, the stress at the outside will be the same as that found by the common formula.

In Lamé's formula it is assumed that the longitudinal stress and longitudinal elongation are constant for all points in the vessel. The tangential stress at the inside of the shell is

$$T_1 = p\left(\frac{d_1^2 + d_2^2}{d_2^2 - d_1^2}\right) \qquad (5)$$

and at the outside

$$T_2 = p\left(\frac{2d_1^2}{d_2^2 - d_1^2}\right) \qquad (6)$$

by substituting $d_1 + 2t$ for d_2 and reducing, we have

$$T_1 = \frac{p}{2}\left(\frac{d_1^2}{d_1 t + t^2} + 2\right) \qquad (7)$$

$$T_2 = \frac{p}{2}\left(\frac{d_1^2}{d_1 t + t^2}\right) \quad (8)$$

and the outside stress is less than the inside stress by the amount of the internal pressure.

Claverino produced a formula from a consideration of the true stresses involved, that is, those due to the deformations.

His formula is

$$T_1 = \frac{p}{3}\left(\frac{d_1^2 + 4\,d_2^2}{d_2^2 - d_1^2}\right)$$

making $d_2 = d_1 + 2t$ as before, we have

$$T_1 = \frac{p}{12}\left(\frac{5d_1^2}{d_1 t + t^2} + 16\right) \quad (9)$$

$$T_2 = \frac{5p}{12}\left(\frac{d_1^2}{dt + t^2}\right) \quad (10)$$

Birnie's formulas were modified by Merriman, and when so modified, are the same as Claverino's.

Claverino, Birnie, and other ordnance officers are responsible for the work done during the years from 1880 on. They studied the theories bearing on solid and hooped guns, and Birnie's work is today used by the United States Government as the basis of design.

There are some confirming stress-strain tests that show that Claverino's formulas above give results very close to the actual stresses, but there should be more confirmation. It is therefore suggested that every opportunity be taken to get stress-strain measurements on tanks that are built.

An example may be of interest.

Let us assume a shell 48 inches inside diameter, 2 inches thick under 2,000 lb. internal pressure. What are the stresses by the various formulas?

	At inside of shell	*At outside of shell*
Common	24,000	24,000
Barlow	26,000	22,650
Lamé	25,040	23,040
Claverino	21,860	19,200

Written Discussion by Clifford W. Bates† of Paper on Calculation of Stresses in Pipe*

The formulae mentioned by Mr. Miller have very different appearances in the forms in which they are given, and in their usual forms in the text books they differ much more. In these forms, or in the original forms, it is almost impossible to estimate the differing results which will be obtained unless complete, and in some

*The subject, "Calculation of Stresses in Pipes" was covered in Mr. Miller's paper on "The Design of Welded Joints," printed in April, 1926 issue of Journal, and presented at Annual Meeting, A. W. S., April, 1926.

†Asst. Chief Engineer, Philadelphia Electric Co.

cases, very exact calculations are made. It is, however, possible to rearrange these equations so that comparisons may be easily made and so that the calculations are much facilitated.

Common Formula: $T = \frac{pd}{2t}$ Strictly speaking, this applies only to thin walled pipes, but it is used as the basis of comparison of the various formulae since its second member occurs as a factor in all the other forms.

Barlow's Formula: $T = \frac{pd}{2t} + p = \frac{pd}{2t}\left(1 + 2\frac{t}{d}\right)$

Lamé's Formula: $T = \frac{p}{2}\left(\frac{d^2}{dt + t^2} + 2\right) = \frac{pd}{2t}\,\frac{1 + 2\frac{t}{d} + 2\frac{t^2}{d^2}}{1 + \frac{t}{d}}$

and expanded into a series:

$$T = \frac{pd}{2d}\left(1 + \frac{t}{d} + \frac{t^2}{d^2} - \frac{t^3}{d^3} + \frac{t^4}{d^4} + \ldots\ldots\right)$$

Clavarino's Formula for short tubes with closed ends:

$$T = \frac{p}{12}\left(\frac{5d^2}{dt + t^2} + 16\right) = \frac{5}{6}\,\frac{pd}{2t}\,\frac{\left(1 + \frac{16}{5}\left(\frac{t}{d}\right) + \frac{16}{5}\left(\frac{t^2}{d^2}\right)\right)}{1 + t/d}$$

and in expanded form:

$$T = \frac{5}{6}\,\frac{pd}{2t}\left(1 + \frac{11}{5}\,\frac{t}{d} + \frac{t^2}{d^2} - \frac{t^3}{d^3} + \frac{t^4}{d^4} + \ldots\ldots\right)$$

$$= \frac{pd}{2t}\left(1 - \frac{1}{6} + \frac{11}{6}\,\frac{t}{d} + \frac{5}{6}\,\frac{t^2}{d^2} - \frac{5}{6}\,\frac{t^3}{d^3} + \frac{5}{6}\,\frac{t^4}{d^4} + \ldots\ldots\right)$$

In the final forms given above, it is seen that all of these expressions are essentially similar and all (with the exception of the last) give the same results when the pipe walls are of negligible thickness compared to the diameter. In each case, the total of the terms inside the parenthesis following unity gives the fractional difference between the formula being considered and the common formula, one or two terms of the series being sufficient ordinarily.

As an illustration of the magnitude of the disagreement of the various formulae the following comparison is given:

Inside dia.	12″		48″		10″	
Thickness	¼″		2″		1″	
t/d	1/48 = 0.02083		1/24 = 0.04167		0.1	
Pressure (lbs./sq. in.	500		2000		2000	
	Fract. Diff.	Stress, lb./sq. in.	Fract. Diff.	Stress, lb./sq. in.	Fract. Diff.	Stress. lb./sq. in.
Common	.....	12,000	.....	24,000	....	10,000
Barlow	0.0417	12,500	0.0833	26,000	0.200	12,000
Lamé	0.0213	12,255	0.0433	25,040	0.1091	11,091
Clavarino	—0.1301	10,440	—0.0889	21,860	+0.0240	10,240

It is interesting to note that the common formula gives almost identically the same values as Lamé's formula if the mean diameter of the pipe is used instead of the inside diameter for d in the formula. Since Lamé's formula gives results which are probably

more nearly correct than any of the others in common use and any error arising from its use is on the safe side, it would seem desirable always to use the common formula, but to use the mean diameter for d of the formula.

Recent tests and theoretical investigation based on the theory of elasticity indicate that the correct results (for long pipes at least) lie between those given by Lamé's and Barlow's formula and that Claverino's formula is questionable even with closed short pipes.

Oxy-Acetylene Welding Sheet Aluminum

JOSEPH W. MEADOWCROFT†

Many efforts have been directed toward the oxy-acetylene welding of sheet aluminum and although it has been welded very successfully, the methods used have been unsatisfactory, in that they are inefficient, slow and expensive. This problem has been solved and sheet aluminum can be welded with the same thoroughness and at a much greater speed than sheet metal. This operation, of course, can only be accomplished by using a rod or strip completely covered with flux, or a filler body.

The filler body must be of a suitable material and can be of any desired shape, size or dimension, to which is applied a thin coating of flux composition of such character and nature, and applied in such a manner as to adhere closely to the surface of the filler body and when so coated may be carried in stock until required in effecting the welding together of aluminum sheets.

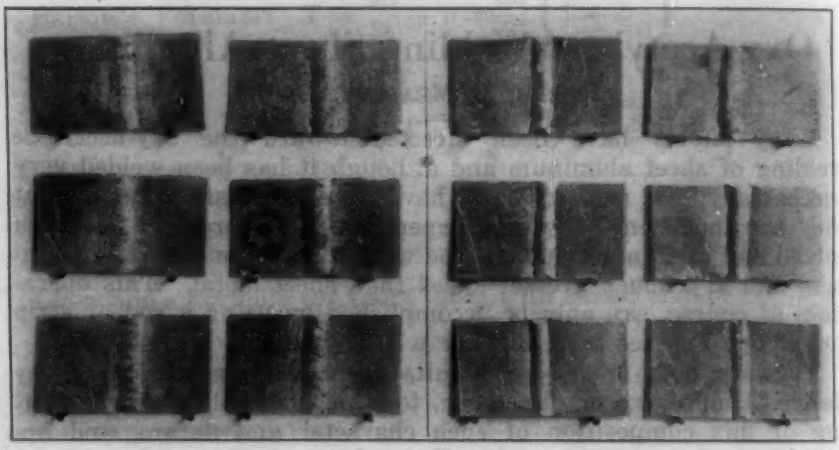
The filler rods or strips must be covered with a flux which will not readily absorb moisture or be materially impaired by handling, nor by lapse of time between the application of the flux and using of the filler rods coated therewith.

In preparing the flux, it has been found convenient and satisfactory to grind the mixed ingredients for a sufficient length of time to reduce the mixture to a condition of smoothness. This can be accomplished in many different ways but it has been found that by grinding the mixture in a rolling ball grinder or rumbler for a specified time period the results are very satisfactory. When the mixture has been reduced by a grinding operation to a degree of smoothness which permits it to mix freely with water, a sufficient quantity of water is added during a continuation of the grinding operation to bring the mixture to approximately the consistency of light cream. When brought to this condition of smoothness and consistency it can be applied to the filler rods but it is necessary to properly prepare filler rods or strips before coating, otherwise it would be impossible for the flux to adhere to them. This is generally accomplished by dipping the filler rods in kerosene, gasoline, alcohol, benzol, or some other hydro-carbon. Before applying the flux coating to the filler rods it has been

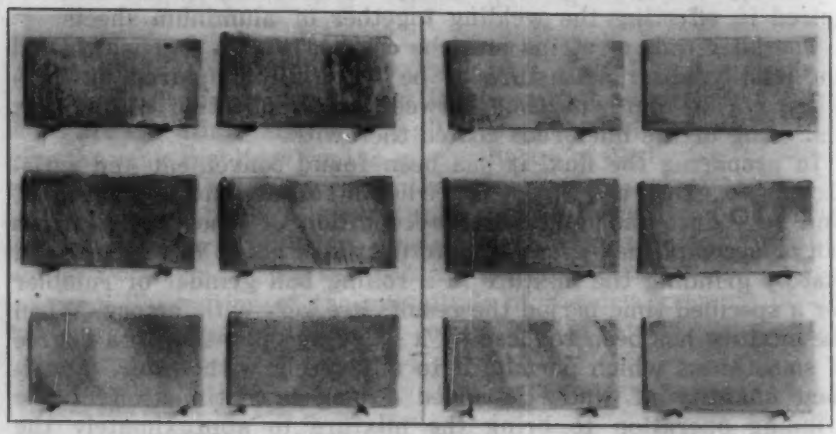
†Supt. E. G. Budd Manufacturing Co.

found desirable to reduce the surface of the filler rods or strips to a condition which will permit the flux composition to take an immediate hold on such surface. To accomplish this it has been found convenient and efficient to dip the filler rods or strips after it has been cleansed, as above prescribed, into a chemical

Oxy-Acetylene Welding Sheet Aluminum
Thickness .040 inches



Outside Weld Unfinished | Inside Weld Unfinished



Outside Weld Finished | Inside Weld Finished

for a certain time period, and then subject the rod or strip to a bath of clear cold water. This treatment serves to put a bright finish on the surface when applied thereto, and to be indefinitely retained thereon. After the filler rod and flux composition has been prepared as above prescribed, the flux may be applied to the filler rods in any suitable or convenient manner. It has been

found very efficient to dip them and after dripping, air dry them. When the filler rods are coated in the above manner, we are ready to use, in effecting the autogenous welding together of sheet aluminum, an oxy-acetylene or an oxy-hydrogen flame. In effecting the welding operation, the welding operator is free to carry on his work without successive interruptions, thereby greatly increasing his speed and saving materially on his gases. By employing scrap material for a filler rod, a saving of approximately 70 per cent is effected, and there is no waste in the flux composition. In the actual use of this method of welding aluminum sheets, the speed of the welding operation is increased and hence, the production costs are lowered to the extent of 50 per cent as compared with other methods of welding previously employed. In this method of welding it is not necessary to prepare the joints of metals to be welded by cleaning, polishing, etc., but as the same procedure as that used on sheet metal can be followed out exactly, the construction of the joints may remain exactly the same. Our welding engineers and metallurgists have recommended for years, that the edge of the metal be turned up at a right angle and it was a first class recommendation, but not necessary today.

Below are former rules for welding sheet aluminum which now can be dispensed with:

1. Cleaning edges to be welded and placing them closely together or turning the flanges up at a right angle.
2. Heating the line of weld with a torch until the edges are at an approximate welding heat.
3. Heating the end of the welding wire and dipping it into flux, leaving such flux adhere to wire.
4. Leaving the welds cool slowly.

Today the welding of sheet aluminum is a simple welding proposition and most any commodity can be manufactured from sheet aluminum and constructed so that oxy-acetylene welding of same can be accomplished without any fear of failure in producing high class welds or of not being able to procure aluminum operators to meet with the required production.

Operators can be instructed very quickly in the use of this method of welding sheet aluminum and in most cases a young man or young woman who has had a week or ten days' training can be placed on production work.

X-Ray Tests of Welds

P. W. SWAIN†

The remarkable growth of the application of fusion welding in recent years has been paralleled by the intensive scientific study of materials, apparatus and processes. There still remain, however, a few problems for which no complete solution has yet been found. In spite of the demonstrated fact that the work of well-trained and properly supervised welders (using either the oxy-acetylene torch or the electric arc) is dependable, there exists a demand for some method of testing a weld without subjecting it to stress.

At present the most widely accepted test of welds as applied to pressure vessels, is the so-called "hammer test" in which the vessel is struck vigorously with a hammer in the region of the weld while subjected to a fluid pressure considerably in excess of the operating pressure. This test has proved to be of great value, as has the routine testing to destruction of occasional samples of a welder's work. The knowledge that such checks may be applied at any time without warning tends to keep all his work up to a high standard.

Valuable as are these methods of testing, there is still, as has been pointed out, a demand for some simple and reliable means of locating hidden defects in a weld without the application of force. At least two methods of accomplishing this has been suggested. One is a species of magnetic testing designed to reveal the existence of breaks in the sound metal due to internal stress, incomplete fusion, gas pockets or particles of oxide or other foreign matter. Some progress has been made with testing devices of this sort, although they have not as yet advanced beyond the laboratory stage.

The other method of testing welds without force is so obvious that it has been suggested by almost everybody from professors of physics to plumber's helpers. That is the X-ray.

For years the X-ray has been an invaluable aid in medicine and surgery. With it buried bullets are located, broken bones are inspected before and after setting, and even the heart beat is watched. The proposal that the X-ray be used to locate defects in welds is, then, a reasonable one. In fact, it has already been used in the testing of metals. An interesting recent example was the X-ray study made of the castings for the 1,200-lb.-pressure turbine built for the Edgar Station of the Boston Edison Company.[1] In this way blow holes were discovered in some of the castings before machining.

To study the possibilities and limitations of the X-ray for testing welded joints, *Power* some sonths ago proposed a special ex-

†Editorial Staff, "*Power*."

[1] See *Power*, June 30, 1925.

perimental investigation and was fortunate to secure the cooperation of the Union Carbide and Carbon Research Laboratories and the Watertown (Mass.) Arsenal. The X-ray examination was made by F. C. Langenberg, metallurgist of the Watertown Arsenal. All other experimental work was done by J. M. Keir at the Union Carbide and Carbon Research Laboratories, Long Island City, N. Y., under the supervision of S. W. Miller. The accompanying photographs, as well as the reports upon which this article is based, were supplied by these two laboratories.

Two 12x9-in. half-inch boiler plates were scarfed at 45 deg. along one long edge of each and welded together. This type of joint is known as the single-V 90-deg. bevel. The 12-in. weld was divided into four zones of about 3-in. each. These zones are indicated on the left of Fig. 1, which shows the welded plate after completion of the X-ray tests and laying out for cutting the physical test specimens. According to the original notes of the welder the jobs done in the four zones were as follows:

Zone 1—Bad weld. Welded at bottom with small tip, then melted in rod and made good job at top.

Zone 2—Good weld.

Zone 3—Poor weld. Some laps. Covered up slag and fused to V, but bad in center.

Zone 4—Fair weld. Rubbed metal along side with rod and got to stick in spots.

It should be particularly noted that these comments were made at the time of welding and were therefore not influenced by any knowledge of the results of the tests. The fact that the general conclusions from the tests agreed with the welder's preliminary judgment reinforces the claim of welding experts that a skilled welder can always tell when he is doing a good job.

After welding, the specimen was sent to the Watertown Arsenal, where the six X-ray photographs reproduced herewith (Figs. 3-8) were made. To understand these photographs it is first necessary to have a general idea of how they were made.

In taking X-ray pictures no lens is used. The X-ray tube is placed above the object to be studied and a photographic film below. The rays move out in straight lines from the bulb, penetrating the object in inverse proportion to the resistance encountered. What strikes the film is nothing but a "shadow" of variable darkness—such a shadow as might be cast on a piece of white paper by a candle light passing through a piece of mottled glass. X-rays do not pass through iron as easily as through flesh, but with a sufficiently long exposure they will register.

Where the rays traverse a cavity in the metal, the resistance is thereby reduced and the shadow lightened. Conversely, extra-dense metal (or greater thickness) makes the shadow deeper. X-rays, like ordinary light, turn the photographic film dark (after

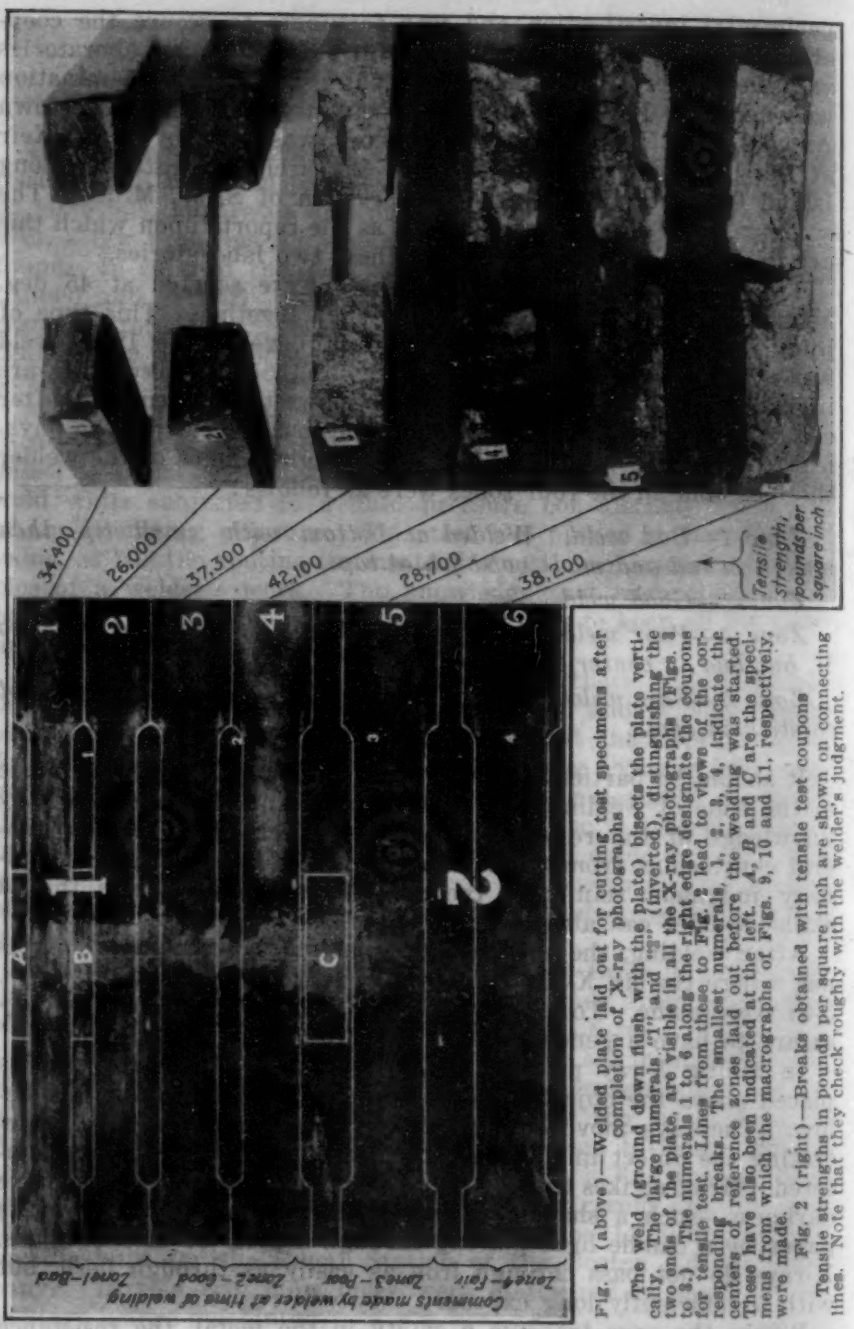


Fig. 1 (above)—Welded plate laid out for cutting test specimens after completion of X-ray photographs

The weld (ground down flush with the plate) bisects the plate vertically. The large numerals "1" and "2" (inverted), distinguishing the two ends of the plate, are visible in all the X-ray photographs (Figs. 1 to 3.) The numerals 1 to 6 along the right edge designate the coupons for tensile test. Lines from these to Fig. 2 lead to views of the corresponding breaks. The smallest numerals, 1, 2, 3, 4, indicate the centers of reference zones laid out before the welding was started. These have also been indicated at the left. *A*, *B* and *C* are the specimens from which the macrographs of Figs. 9, 10 and 11, respectively, were made.

Fig. 2 (right)—Breaks obtained with tensile test coupons

Tensile strengths in pounds per square inch are shown on connecting lines. Note that they check roughly with the welder's judgment.

development); the developed film is in effect a reversed shadow. The deeper parts of the shadow show light and the light parts show dark.

If a print is made from the film, the shadow is again reversed back to its original condition.

All the accompanying photographs correspond in appearance to the prints rather than the films; that is, they are light where the X-rays got through easily and dark where the resistance was greater. Thus light streaks or spots indicate cavities or cracks or at least the presence of some substance with less resistance to the rays than pure sound metal.

Dark patches indicate greater resistance. This is not necessarily due to greater density of the metal. The welds show darker than the adjacent metal because they were slightly thicker in spite of the fact that the weld was ground down close to the plate.

Being nothing but a shadow picture, an X-ray photograph is affected greatly by the direction of the rays in respect to the object. For instance, if a crack exists it should show more plainly when turned "edge-on" to the rays. A thin crack whose plane was at right angles to the rays would not be expected to have much effect on the rays.

The two sides of the V, as already noted, make an angle of 45 deg. with the plane of the plate. To reveal any flaws accumulating along these surfaces, X-ray photographs were taken with the rays approaching the weld first from the left and then from the right, and in both cases at an angle of 45 deg. with the surface of the plate. In addition, an ordinary X-ray photograph was taken with the rays striking the weld at right angles to the surface.

Because of the size of the specimen it was necessary to take two such sets of three photographs each. The two sets cover the full 12-in. length of the weld and overlap considerably at the center.

Before making the photographs, the extra metal on the weld was ground down as close to the surface of the plate as possible, as already pointed out. This was necessary to avoid the shadow effect of variable thickness.

After the X-ray work had been completed, the plate was returned to the Union Carbide and Carbon Research Laboratories to be cut up for physical tests. Fig. 1 shows the plate marked up for cutting out the test specimens. The five tensile coupons are identified by the numbers on the right of the photograph. These were cut out and tested for ultimate strength. Additional information was gained by a study of the appearance of the corresponding breaks, as shown in Fig. 2. The ultimate strengths of the various coupons are given on the cut. Macroscopic[2] photographs were made of sections taken from *A*, *B* and *C*. These are shown in Figs. 9, 10 and 11.

To avoid annoying the reader by requiring him to refer constantly from text to photograph, most of the detailed observa-

[2] A macroscopic photograph is one made with a small magnification.

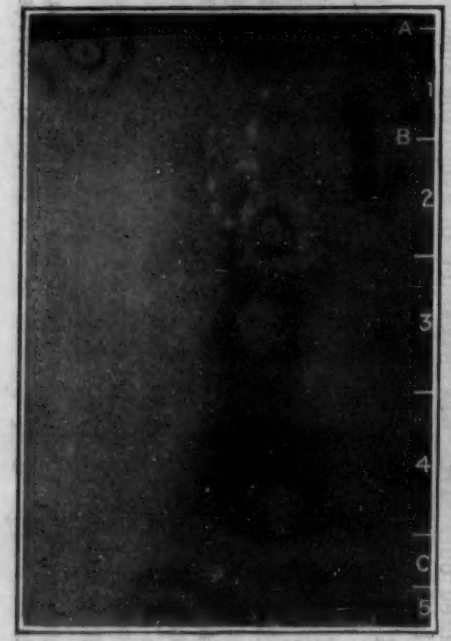


Fig. 3—Tube at left and rays parallel to left scarf

Defects are visible in region of Coupons 1 and 2. These defects roughly follow two vertical lines, joined by a loop at the bottom, suggesting that they lie along the scarfs. Middle welding (Coupons 3 and 4) looks good. Large void is visible in *C*.

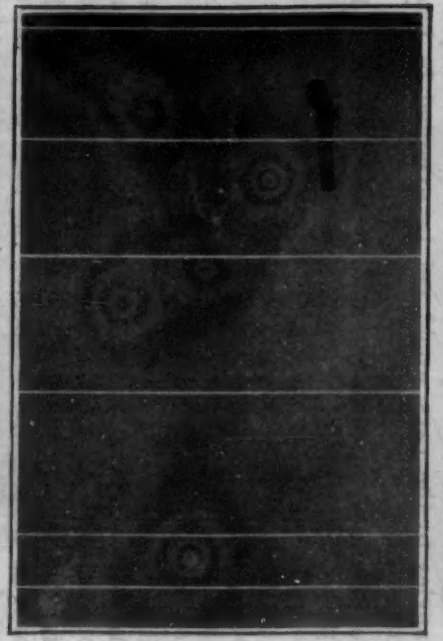


Fig. 4—Tube directly over weld with rays perpendicular to plate

Small voids and oxide inclusions seem to be indicated by the light spots in Coupons 1 and 2. Figs. 3 and 5 indicate that these defects are mostly along the scarfs. The welding metal appears denser than metal of the plate because of its greater thickness.

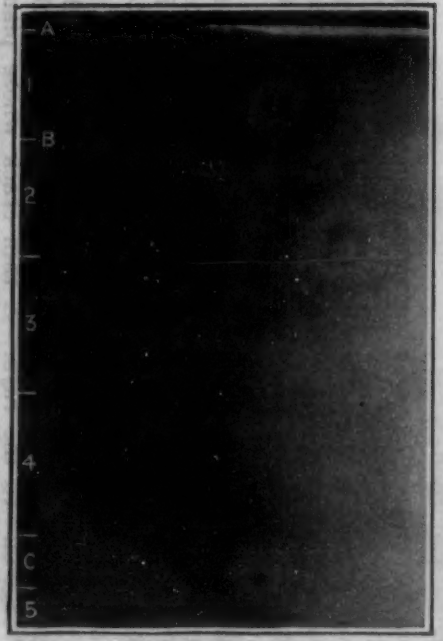


Fig. 5—Tube at right and rays parallel to right scarf

The light vertical line in Coupons 1 and 2 seems to indicate a series of voids along right side of scarf. Study of the sideways shifting of the void in *C* in Figs. 3, 4 and 5 indicates that it and the smaller nearby defects are in the body of the weld.

Fig. 6—Tube at left and rays parallel to left scarf

In this photograph there is no clear indication of a defect along the scarf in Coupon 6 as was expected to be shown by the tilting of the plate. Note voids in *C* and in Coupon 5.

Fig. 7—Tube directly over weld with rays perpendicular to plate

Line of junction at the bottom of the *V* in Coupons 3 and 4 may be seen, indicating lack of penetration. Voids and inclusions in *C* and Coupon 5 show up more clearly.

Fig. 8—Tube at right and rays parallel to right scarf

The weld in Coupons 3 and 4 seems to be homogeneous. The defects in *C* and Coupon 5 show up again. The weld in the lower end of the plate appears to be sound as in Figs. 6 and 7.

tions have been incorporated in long captions. The following comments are in the nature of a summing up of these observations.

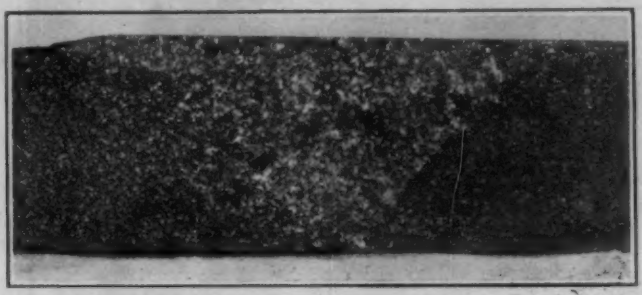


Fig. 9—A macroscopic view of the weld at specimen *A* (see Fig. 1)
A few small voids may be noted on the surfaces of the scarf and in the body of the weld. Similar defects are indicated by the X-ray in Figs. 3, 4 and 5.

In Zone 1, the welder deliberately did a bad job. His comments were "Bad weld. Welded at bottom with small tip, then melted in rod and made good job at top." This is the region covered by

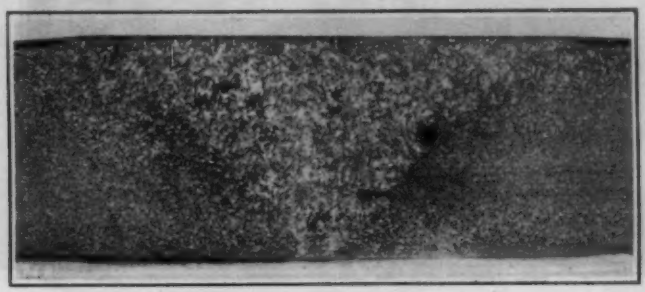


Fig. 10—A macroscopic view of the weld in specimen *B* (Fig. 1)
Small voids are here visible along the scarf and in the body of the weld. These seem to be satisfactorily shown in Figs. 3, 4 and 5.

the test coupons 1 and 2 and macroscopic specimens *A* and *B* as indicated in Figs. 1, 2, 3, 4, 5, 9 and 10. The X-ray photos (Figs. 3, 4 and 5) showed what seem to be poor penetration and also other defects along the two scarfs in this region. Some defects —porous metal and oxide inclusions—also seemed to be present in the body of the weld. Tensile Coupon 1 showed the ultimate strength of 34,400 lb. per sq. in., while Coupon 2 dropped off to 26,000, giving an average for Zone 1 of only 30,200 lb. The poor fusion may be seen by studying the breaks in Fig. 2. These followed one surface of the V. Some small voids along the faces of the V and in the body of the weld may be noted in Figs. 9 and 10.

Zone 2 was labeled "good weld" by the welder. The tensile

tests of Coupons 3 and 4 (37,300 lb. and 42,100 lb. respectively, with an average of 39,700 lb.) bear out his judgment. The X-ray failed, however, to show the lack of fusion at the bottom of the V which may be seen on the break of Coupon 4 in Fig. 2.

The welder referred to Zone 3 as "Poor weld. Some laps. Covered up slag and fused to V, but bad in center." The corresponding test specimens are *C* and Coupon 5. All six X-ray photographs showed a large void and some small ones in *C*. These are clearly shown in Fig. 11. The existence of many voids and inclusions in Coupon 5 as shown in the X-ray photographs is borne out by the low tensile test of 28,700 lb. obtained with this speci-

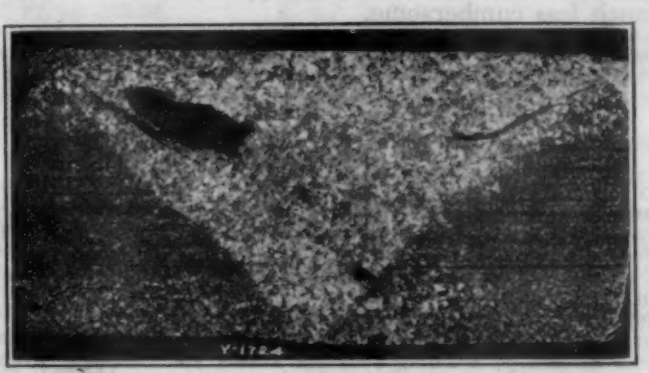


Fig. 11—Macroscopic view of the weld in specimen *C* (Fig. 1)
The large void shown is clearly visible in all the X-ray pictures. It is evident that a considerable portion of the scarf has been poorly fused, as shown by the sharp line of demarcation. This is most prominent on the lower half of the left-hand scarf. The X-ray failed to reveal this defect.

Fig. 12—Side view of break in coupon 4 (Figs. 1 and 2)
Insufficient fusion along the bottom of the *V* is clearly shown, as in a fissure stretching across the weld. This has probably been caused by a "lap," that is, by the welder permitting fused metal to flow over a unfused surface. The X-ray did not reveal this serious defect.

men. The X-ray did not, however, reveal the lack of fusion along the faces of the scarf which is evident in the break of Coupon 5 (Fig. 2).

Zone 4, which the welder describes as "Fair weld. Rubbed metal along side with rod and got to stick in spots," showed no material defects in the X-ray photographs. Yet the break in Coupon 6 (Fig. 2) indicates very poor fusion along the face of the V.[2]

To sum up, the tests made show definitely that the X-ray is capable of revealing such defects as gas pockets, oxide inclusions and cracks nearly parallel with the rays, but that with the methods employed there will be little if any indication of poor fusion. The apparent shortcomings of the X-ray may possibly be overcome by future advances in X-ray technique. For general application of the X-ray to the testing of welds, the apparatus should also be made much less cumbersome.

[2] The high tensile test of 38,200 lb. obtained with coupon 6 seems to be one of those occasional freaks difficult to explain.

Current Welding Literature

Airplane Joints. Automotive Abstracts, Vol. IV. (May 20, 1926), p. 143.

Aluminum Alloy Castings, Welding. A. Eyles, Machinery (London) (March, 1926), Vol. 32, pp. 560-62. Preparing Surfaces for Welding, Welding Fluxes, Methods of Applying Flux, Preheating the Work, Welding Material, Making the Weld.

Aluminum and Its Alloys, Autogenous Welding of. A. Eyles, American Machinist (Feb. 18, 1926), Vol. 64, pp. 275-9. Difficulties to be contended with; Pure gases necessary; Welding rods for sheets and castings; Preparing the Joints; Goggles and the color of the glass.

Aluminum, Some Notes on the Welding of, E. T. Painton, Engineering (Feb. 12, 1926), Vol. 141, pp. 189-90.

An Unfinished Test. Welding Engineer (May, 1926), Vol. 11, pp. 19-20.

Arc Welding, Broadening Field of, A. G. Bissell, Machinery (London) (March, 1926), Vol. 32, pp. 550-51. Arc Welding in Shipyards and Street Railway Shops; Application in Steel Mills; Oil Industry and Airplane Construction; Use of Welding Process in Steel Tank Manufacture; Building Construction and Mining Industry.

Arc Welding Heavy Copper Castings, P. M. Rauscher, Welding Engineer (May, 1926), Vol. 11, pp. 17-18.

Arc Welding Machine. International General Electric Co., N. Z. Pat. 54174. Patt Off. Jnl. (Dec. 31, 1925), Vol. 14, pp. 762-3.

Arc Welding Metallic, P. L. Roberts, Mechanical World (Jan. 15, 1926), Vol. 79, pp. 46-7. Welding of Cast Iron, Exparsion and Contraction, Preparation, Mild-Steel Electrode, Gap Method, Studding Method, Preheating, The Cast-Iron Electrode Method.

Arc Welding, Method for Stating an Arc in a Welding Apparatus and the Like, F. L. Walker, Jr., U. S. Pat. 157083. Off. Gas. (Jan. 26, 1926), Vol. 342, pp. 801-2.

Arc Welding Mild Steel, Economy of Wirtschaftlichkeit der Lichtobogenschweissung von Flusseisen, K. Miller, Siemens Ztsch. (Nov., 1925), Vol. 5, pp. 457-64.

Arc Welded Pressure Tanks Safe? Power, Vol. 63 (May 4, 1926), p. 690.

Cutting Cast Iron With the Torch, The Welding Engineer (May, 1926), Vol. 11, pp. 25, 26.

Design of Welded Joints, S. W. Miller, Power (May 11, 1926), Vol. 63, p. 731.

Electric Welding in Belgium, Recent Applications of, D. LaGrange, Bulle. Technique Assoc. de Ing., Sortis de L'Ecole Poly. (1924), No. 5 and 6.

Electric Welding, La soudure electriqui, J. Maurice, Ann. de' l' Energie et des Aples, Indust. (Jan. 25, 1926), No. 19, pp. 3-7.

Electric Welding, Automotive Abstracts, Vol. IV. (May 20, 1926), p. 157.

Electric Welding, British Thomson-Houston Co., Ltd., Brit. Pat. 244155. Ill. Iff. Jnl. (Feb. 3, 1926), p. 6599.

Gas Welded Bonds on the Erie. C. A. Nichols, Acetylene Journal (May, 1926), Vol. 27, pp. 545-547. Early tests made on Kent Division, the 1925 bonding program on the Marion Division covered 546 miles of track, substantial saving made also where circuits were not extended.

Keeping the Welder in Condition, M. D. Goodman, Welding Engineer (May, 1926), Vol. 2, p. 31. How arc welders are built, Keeping machines in good order, For arc welding sheet metal, Not too much speed on Gas Engine sets.

Oxy-Acetylene Tips (April, 1926), Vol. 4. Keeping in Pace with Demand, p. 168; The Only Way to Do It, p. 157; Welded to a Mountain Side, p. 160; From Red Figures to Black, p. 164; The Blowpipe Does the Heavy Work, p. 173; Operating an Air Sift With Natural Gas, p. 174; Sound Castings for Sanitary Ware, p. 175; Oxwelded Radio Towers, p. 159; Regulators Should be Handled Carefully, p. 161; Steel Pipe Joints, p. 162; Bit by Bit Oxwelded, p. 173; Importance of Correct Welding Rods, p. 176.

Oxy-Acetylene Welding of Copper, S. W. Miller, Acetylene Journal (May, 1926), Vol. 27, pp. 533-36.

Heat Distribution in the Arc, J. B. Green, Welding Engineer (May, 1926), Vol. 2, pp. 21-24. Description of thermocouple action, Heat explained, Thermocouple theory of arc heat distribution, Effect of Arc Length, Effect of arc vapor resistance, Effect of polarity of welding current, Effect of thermocouple polarity, Effect of radiation.

Riveted and Welded Trusses Tested to Failure, Engineering News-Record (May 20, 1926), Vol. 96, p. 826.

Two Improved Methods of Electric Welding, Engineering News-Record (April 22, 1926), Vol. 96, p. 647.

Two New Processes of Welding, Mechanical Engineering (May, 1925), Vol. 48, pp. 515-516. The Atomic-Hydrogen Welding Process, Arc Welding in Hydrogen and other Gases

Using the Torch in the Power Plant—11, L. A. Cowles, Power (May 4, 1926), Vol. 63, pp. 673-674. Cutting torch, action of cutting explained.

Welded Pressure Tanks, Power, Vol. 63 (May 11, 1926), p. 725.

Welded Steam Pipe Lines in Cleveland, Ohio, Acetylene Journal (May, 1926), Vol. 27, pp. 540-544.

Welder, Automatic, O. A. Kenyon, U. S. Pat. 1571924. Off. Gaz. (Feb. 2, 1926), Vol. 343, p. 224.

Welding Copper Fireboxes, Harold Young, The Welding Engineer (May, 1926), Vol. 2, pp. 27-29.

X-Ray Tests of Welds Reveal Some Defects, But Not All. Power, Vol. 63 (May 25, 1926), pp. 800-803.

YES! FOR UNIFORM AND RELIABLE WELDING RESULTS
SPECIFY HOLLUP WELDING WIRE
WANAMAKER COATED AND REX BARE ELECTRODES
REX GAS WELDING RODS — REX ACCESSORIES
Write for literature and free samples.
Manufactured by
C. H. HOLLUP CORPORATION
3333 W. 48th PLACE CHICAGO

Year Book
American Welding Society
1926

The Society expects to issue its first Year Book as the August issue of the Journal. Among other things, it will include a description of the American Welding Society, its aims, functions and some of its accomplishments, description of the welding industry and of the American Bureau of Welding, Constitution and By-Laws of the Society and the Bureau, a list of the various technical and research committees and their membership, an alphabetical and geographical list of the members of the Society, a classified directory of welding apparatus and supplies.

Copies of this Year Book will be sent free to any prospective member upon request.

If you want your name included in this membership directory, membership should be taken out in the Society before July 10th.

Members should return their cards, giving present connections and address as soon as possible.

The Standard of Quality in Gas Welding and Cutting Equipment

Economy Record No. 1
25 Torchweld Cutting Torches
Average Service 7 Years
Total Cost for Tips and Repairs, Average per mo., 78c

SAFETY—ECONOMY—DEPENDABILITY
are built into Torchweld Gas Welding and Cutting Equipment

TORCHWELD EQUIPMENT COMPANY
224 No. Carpenter St. *Send for Catalog No. 23-J* Chicago, Ill.

REGO
"LOWER OXYGEN PRESSURE"
Welding and Cutting Equipment
WRITE FOR CATALOG NO. 37
THE BASTIAN-BLESSING COMPANY
252 E. Ontario St., Chicago, Ill.

Weldite
Welding Rod

NEW APPLICATIONS FOR FUSION WELDING

The facilities of our Research Laboratories for solving problems involving Filler Rod are at the disposal of firms and individuals attempting to extend the field of welding.

CHICAGO STEEL & WIRE Co
103rd Street *and* Torrence Avenue CHICAGO

"My Men Always *Want* Wilson Wire"

Use Wilson Type S Machine

Simple, close regulation; a *self-exciting* generator; a commutator that always shows *less temperature rise than any other part of the machine;* a simple, compact control panel; a special resistance unit which can be supplied *for reducing the welding current to as low as 25 amperes* for light work and thin gauge metals; an arc that is easy to strike and easy to maintain—these are some of the features that make the Wilson type S a distinct achievement in electric arc welding. Write today for complete information and prices.

"I really can't afford to use any other wire than Wilson. In the first place, my men *want* Wilson Wire. They know we can get them a grade* of Wilson Wire that's just *right* for any kind of welding they have to do. In the second place, they *know* that no matter what grade*, it will run uniform right through. The result is that when we use Wilson Wire our men have no alibis, and don't need any."

***"Grade" means the analysis of the wire.**

Every man who has had any experience with Wilson Wire will tell you the same thing. He'll tell you that he can select the correct grade (analysis) of Wilson Wire for the kind of metal he's welding—and that *every rod will be just like every other rod* in the grade selected. This means practically perfect welding jobs.

You'll find it pays to insure your welding by using Wilson Wire, because you can secure the *right* grade (analysis) for every kind of metal you weld, and whatever the grade selected, it will run uniform thruout.

Write today for your samples of Wilson "Color-tipt" Welding Wire, indicating the kind of metal you desire to weld.

WILSON WELDER & METALS CO. INC., WILSON BLDG., HOBOKEN, NEW JERSEY

WILSON

WELDING MACHINES AND WELDING WIRE

UNION CARBIDE

World's Best Quality - Highest Gas Yield
Always Uniform - Always Dependable

Packed in Blue and Gray Drums

We have Warehouses in 175 Cities

The product of the originators and developers of the carbide and acetylene industry

QUALITY assured by more than a quarter of a century of experience in selecting raw materials and in perfecting laboratory practice and works processes.

The faithfully sustained quality compels recognition of the economies which go with it.

Union Carbide will keep for years in the original package without deterioration.

Our remarkable nation-wide service and distributing system makes Union Carbide quickly available everywhere.

There is a Union Carbide warehouse near you. Shipment is made same day your order is received.

We supply Union Carbide in Generator sizes—direct to consumer—at factory prices.

Our Blue and Gray Drum is recognized throughout the world, as a symbol denoting Best Grade Carbide, Highest Gas Value, Uniform Dependable Quality and Purest Gas.

UNION CARBIDE SALES COMPANY

Principal Offices: Carbide and Carbon Bldg., New York, N.Y.
Peoples Gas Building, Chicago, Ill. Balfour Building, San Francisco, Calif.

When is oxygen cheap?

CHEAPNESS is relative and depends entirely on how much material, quality and service you get for your money.

Linde Oxygen—for years industry's standard—is sold on a basis of ultimate economy. Linde service, which goes with Linde oxygen, is designed to give to every customer the latest and best information on the use of the oxy-acetylene process. Service men, engineers, consultants, research men, are constantly at work and always at your service to show the latest methods, new applications and greater economies in welding and cutting.

NOT ONLY can you build new tanks advantageously by welding, but old tanks that have given way on the bottom or on the crown can be repaired and reconditioned. Linde Methods tell you how to replace a bottom or a crown by the oxy-acetylene process and Linde engineers can give you suggestions even on design.

THE LINDE AIR PRODUCTS COMPANY

Manufacturers of oxygen, nitrogen, pyrogen, argon and neon
Producers of helium for scientific purposes

General Offices: Carbide and Carbon Building
30 East 42d Street, New York

37 Plants · 105 Warehouses

LINDE OXYGEN

Always on Hand

It is because Prest-O-Lite has an ample supply of cylinders in its 31 plants and 85 warehouses that its 22 District Sales Offices are always able to fulfill every delivery promise for dissolved acetylene. This is the service you need for your oxy-acetylene welding and cutting operations.

THE PREST-O-LITE COMPANY, INC.
Oxy-Acetylene Division
General Offices: Carbide and Carbon Building
30 East 42d St., New York
In Canada: Prest-O-Lite Co. of Canada, Limited, Toronto
31 Plants—85 Warehouses
22 District Sales Offices

Prest-O-Lite
DISSOLVED ACETYLENE

If you must use your blowpipe as a hammer

or leave it in the road to be smashed by the factory truck, pick up the pieces and send them to the nearest Oxweld apparatus repair station.

There are 21 Oxweld repair stations throughout the country. One of them is near you. Mail or express your blowpipe direct to this nearest station and it will be back in service before you know it, for a nominal charge.

Oxweld repair stations are factory supervised and give the same careful service that you would get from the factory direct. Saving time and money for our customers is our main reason for establishing them.

OXWELD ACETYLENE COMPANY

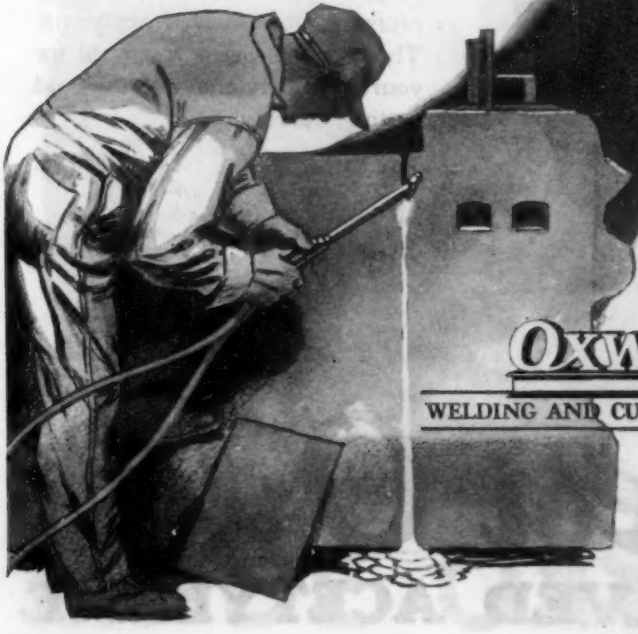
Chicago
1642 Jasper Place

Long Island City, N. Y
Thompson Ave. & Orton St.

San Francisco
1050 Mission Street

OXWELD
Apparatus Repair
Stations

Baltimore
Birmingham
Boston
Buffalo
Chicago
Cleveland
Denver
Detroit
Houston
Los Angeles
Minneapolis
Newark
Omaha
Philadelphia
Pittsburgh
Portland
St. Louis
Salt Lake City
San Francisco
Seattle
Tulsa



Oxweld

WELDING AND CUTTING APPARATUS

W. J. WYATT, President

WYATT METAL & BOILER WORKS

CONSOLIDATION OF

WYATT METAL WORKS AND DALLAS BOILER WORKS

DALLAS, TEXAS

March 4, 1926.

500% increase with G-E Automatic Arc Welders

Mr. E. T. Shiels,
General Electric Co.,
Dallas, Texas.

Dear Sir:

We are enclosing photograph of the Automatic Welder with the clamping device, which we purchased from you about twelve months ago.

We have been using this machine continually ever since it has been installed and about fifty per cent of the time running twenty-four hours a day. We have not had any trouble with the equipment so far and expect to place another order with you in the near future.

Our welded tank business has increased about five-hundred per cent since we installed this machine and we believe that arc welding is still in its infancy.

Yours very truly,

WYATT METAL & BOILER WORKS.

By W. J. Wyatt
President.

WJW:w
Encl.

ARMCO ingot iron

wyatts

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., SALES OFFICES IN ALL PRINCIPAL CITIES

3345

TOBIN BRONZE WELDING
makes emergency repairs permanent

A bad break in the cast iron parts of an automatic machine—

—welded with Tobin Bronze without dismantling

WHEN a break occurs in an automatic machine, the shop is often confronted with a loss in production while a new part is being obtained. Tobin Bronze Welding by the oxy-acetylene process offers a most effective solution to such a difficulty, and saves the cost of new parts.

The photographs show a typical example of a permanent repair made quickly with Tobin Bronze. Since extensive pre-heating was not required, dismantling was unnecessary. The low welding temperature of 1650° F. also prevented shrinkage and made it possible to restore the broken parts to their original alignment. Most important of all, the repair is permanent and the weld is stronger than the original cast iron.

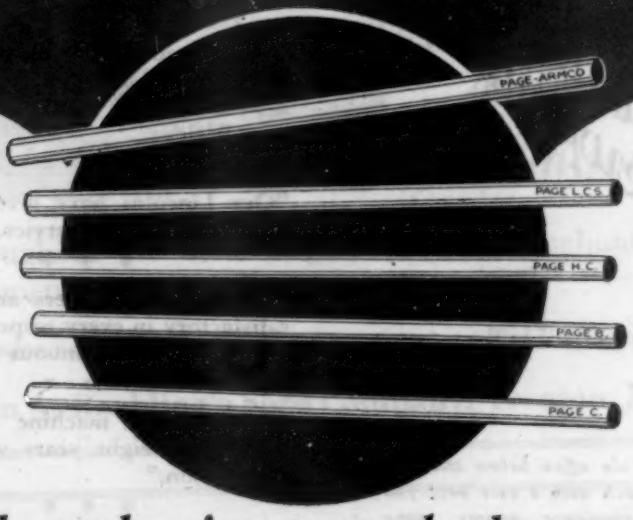
Tobin Bronze Welding Rods, exclusively an Anaconda product, are made solely by The American Brass Company, and "Tobin Bronze" is stamped in the metal.

THE AMERICAN BRASS COMPANY
GENERAL OFFICES: WATERBURY, CONNECTICUT
Offices and Agencies in Principal Cities
Canadian Mill: Anaconda American Brass Ltd., New Toronto, Ont.

TOBIN BRONZE
REG. U.S. PAT. OFF.
WELDING RODS

EXCLUSIVELY AN ANACONDA PRODUCT

PROCESSED
for accurate welding



and each piece marked—

The cause of much unsatisfactory welding has been traced to the use of improper welding wires.

A good welder can regulate his current or flame, and do many other things which tend toward making good welds. He cannot, however, alter the welding characteristics of the wire.

Page has practically solved this problem and taken much of the "guess" from welding.

Every Page Welding Wire and Electrode is "Processed" for the particular type of welding for which it is recommended, and all Page Wires are "shop tested."

As an additional safeguard every Page Wire is plainly stamped with the name and grade and in the case of Page ARMCO Wires additional precautions are taken by painting the ends.

These wires are easily identified and will not become confused in your bins.

We invite you to test Page Wire in your own shop. Write today for samples and interesting literature. No obligation.

PAGE STEEL AND WIRE COMPANY

An Associate Company of the American Chain Co., Inc., of Bridgeport, Conn.

Bridgeport, Connecticut

District Offices: Chicago, New York, Pittsburgh, San Francisco.
In Canada: Dominion Chain Company, Limited, Niagara Falls, Ontario.

PAGE-ARMCO
PROCESSED
Welding Wire and Electrodes

Before you settle on the type of machine— get the users viewpoint

They say

(a new list in each issue)

"It gives me much pleasure to inform you that we have never lost a weld made by the Lincoln Stable-Arc Welder."

* * *

"Our Lincolns have given us perfectly satisfactory service."

* * *

"The Lincoln welders are proving satisfactory in every respect and are in practically continuous service."

* * *

"Our Lincoln machine has operated about eight years with entire satisfaction."

* * *

"Have not had one minute's trouble with the Lincoln welder bought several years ago."

* * *

"Our welders prefer the Lincoln machine."

Any Lincoln office below will put you in touch with a user near you whose experience covers many types of welders. Get his viewpoint based on experience.

"Stable-Arc"

LINCOLN WELDER

Branch Offices
Baltimore
Boston
Buffalo
Charlotte, N. C.
Chicago
Cincinnati
Detroit
Des Moines
Grand Rapids

The Lincoln Electric Co.

General Offices and Factory:
Cleveland, Ohio

The Lincoln Electric Co. of Canada, Ltd., Toronto-Montreal
European Representatives: Allen-Liversidge, Ltd., London

Branch Offices
Indianapolis
Milwaukee
Minneapolis
New York City
Philadelphia
Pittsburgh
Rochester
St. Louis

Distributing agencies in all principal cities.

Exclusive Agencies with Stock:
Ft. Worth, Texas
New Orleans
Los Angeles
San Francisco

Roebling Welding Wire

is

Strong
Tough
Uniform

throughout the same shipment and throughout all shipments.

Conforms to specifications of The American Welding Society

John A. Roebling's Sons Company, Trenton, N. J.

SWEDOX

WELDING RODS, WIRES and ELECTRODES

A Grade for Every Purpose

NONOX SWEDOX
LEKTROX SWEDOX
CASTOX
ARC CARBOX
GAS CARBOX
VANOX

STEELKOTE
LEKKOTE
CYLKOTE
MANKOTE
RAILKOTE

TENSKOTE
DUCTKOTE
DUCTILOX
NICKOX
RAILOX

KROMOX
MANGANOX
ALUMINOX
DRAWN ALUMINUM
BRAZOX

BRONZOX
BRONZKOTE
TOBIN BRONZE
MANGANESE BRONZE
MONEL METAL

TENSILOX
KROMKOTE
NICKOTE
VANKOTE
FLUXES

SEND FOR TESTING SAMPLE

We want every welder in the country—big or small—to be convinced of the *specialized superiorities* of SWEDOX products. We know that a trial *will* convince you. Hence the free offer. Try SWEDOX on your next welding job at our expense.

CHICAGO, ILL.
4545 S. Western Blvd.
Phone: LaFayette 8500

Central Steel & Wire Company

DETROIT, MICH.
5001 Bellevue Ave.
Phone: Lincoln 6780

"We Ship the Same Day"

THERMIT WELDING

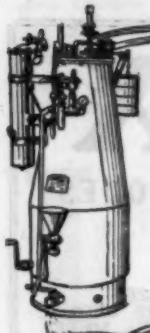
For heavy welding operations in all fields

Railroad Industrial Marine

METAL & THERMIT CORPORATION

120 Broadway, New York

Pittsburgh Chicago Boston S. San Francisco Toronto



Why Experiment?

Torches
Regulators
Generators
Compressors
Manifolds
Preheaters
Paint Sprays
Carbide Lights

Catalog 54?

SINCE the infancy of the industry, expert engineers and skilled workmen have maintained the predominance of Milburn Equipment.

Its acceptance as standard equipment by large industrials, railroads and Government Departments the world over exemplifies Milburn leadership.

THE ALEXANDER MILBURN CO.
Baltimore, Md.

If strength, toughness and ductility of the weld metal are essentials in your weldling requirements, the UNA Process of Welding so successfully used in welding Rail Joints by the Electric Railway Industry, will meet your needs.

Your welding inquiries solicited.

UNA WELDING ANDBONDING COMPANY

1615 Collamer Ave.

CLEVELAND, OHIO

Welding Processes
Welding Rods

UNA

A.C.-D.C. Welders
Welding Supplies

TWO OPERATOR ARC WELDERS

A DISTINCTIVE DEVELOPMENT

PORTABLE VARIABLE VOLTAGE ARC WELDER
FOR TWO OPERATORS

MAXIMUM FLEXIBILITY AS WELL AS GREATEST EFFICIENCY IN GETTING OUT THE MOST WORK UNDER A GREAT VARIETY OF CONDITIONS. WITH THIS MACHINE EITHER OPERATOR CAN REGULATE FOR HIS OWN REQUIREMENTS WITHOUT AFFECTING THE OTHER, AND EITHER OPERATOR MAY USE ANY PROPORTION OF THE CAPACITY OF THE WELDER SO LONG AS THEIR TOTAL DEMANDS ARE NOT GREATER THAN THE RATING OF THE MACHINE. ONE OPERATOR WORKING ALONE CAN USE THE TOTAL CAPACITY FROM EITHER COMMUTATOR.

BULLETIN 133 GIVES FULL INFORMATION
WRITE FOR IT

BURKE ELECTRIC COMPANY

ERIE, PA.

Service Sales Offices:

NEW YORK CHICAGO PHILADELPHIA PITTSBURGH
CLEVELAND DETROIT BUFFALO

Sales Agencies:

CINCINNATI — UNDERWOOD ELEC. CO.
KANSAS CITY — W. T. OSBORN
MILWAUKEE — FRED H. DORNER
TULSA — J. E. ARNOLD
AKRON — BERTHOLD ELECTRIC & ENG'G. CO.
OMAHA — D. H. BRAYMER EQUIPMENT CO.

Your Assurance of High Cutting Efficiency Stamped on Every Airco Oxygen Cylinder

What does this stamp mean To You?

"A saving of 10% in time and material may safely be accepted as correct for any increase of 0.5% in the quality of oxygen of which the minimum purity is 98.5%."
—From an Editorial in Industrial Gases.

AIRCO OXYGEN IS 99.5% PURE IN THE CYLINDER

AIRCO

OXYGEN ACETYLENE CARBIDE
NITROGEN CALORENE NEON

Airco-Davis-Bournonville Oxyacetylene Apparatus

AIR REDUCTION SALES CO.

342 MADISON AVENUE, NEW YORK CITY, N. Y.

51 AIRCO PLANTS 17 DISTRICT OFFICES